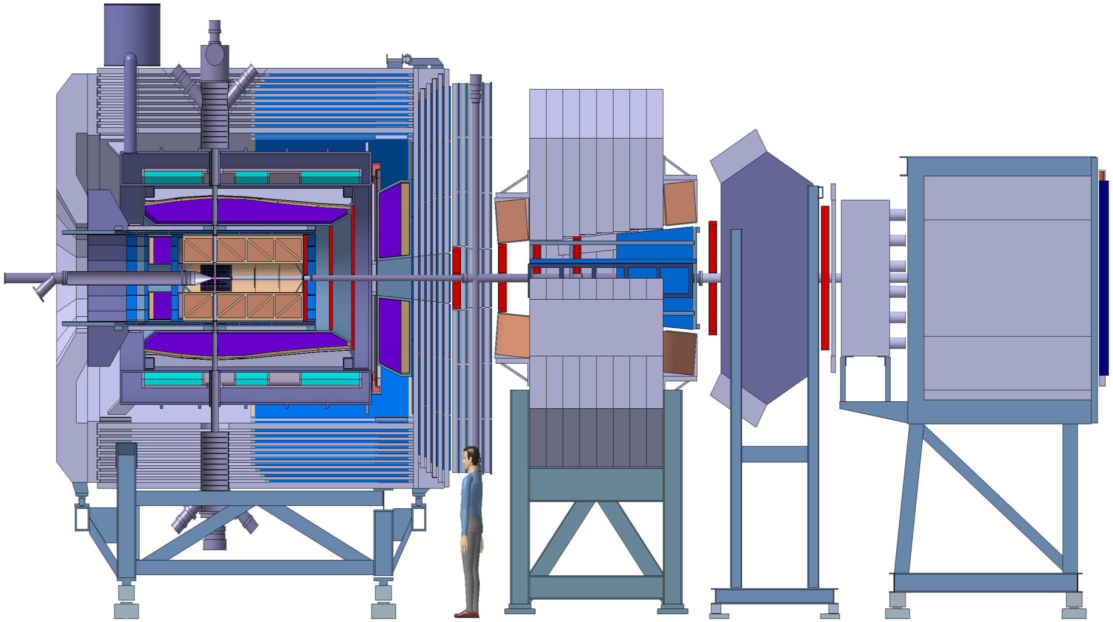
Particle Identification for the PANDA detector

Carsten Schwarz, GSI
for the PANDA Cherenkov group



Overview

Detector

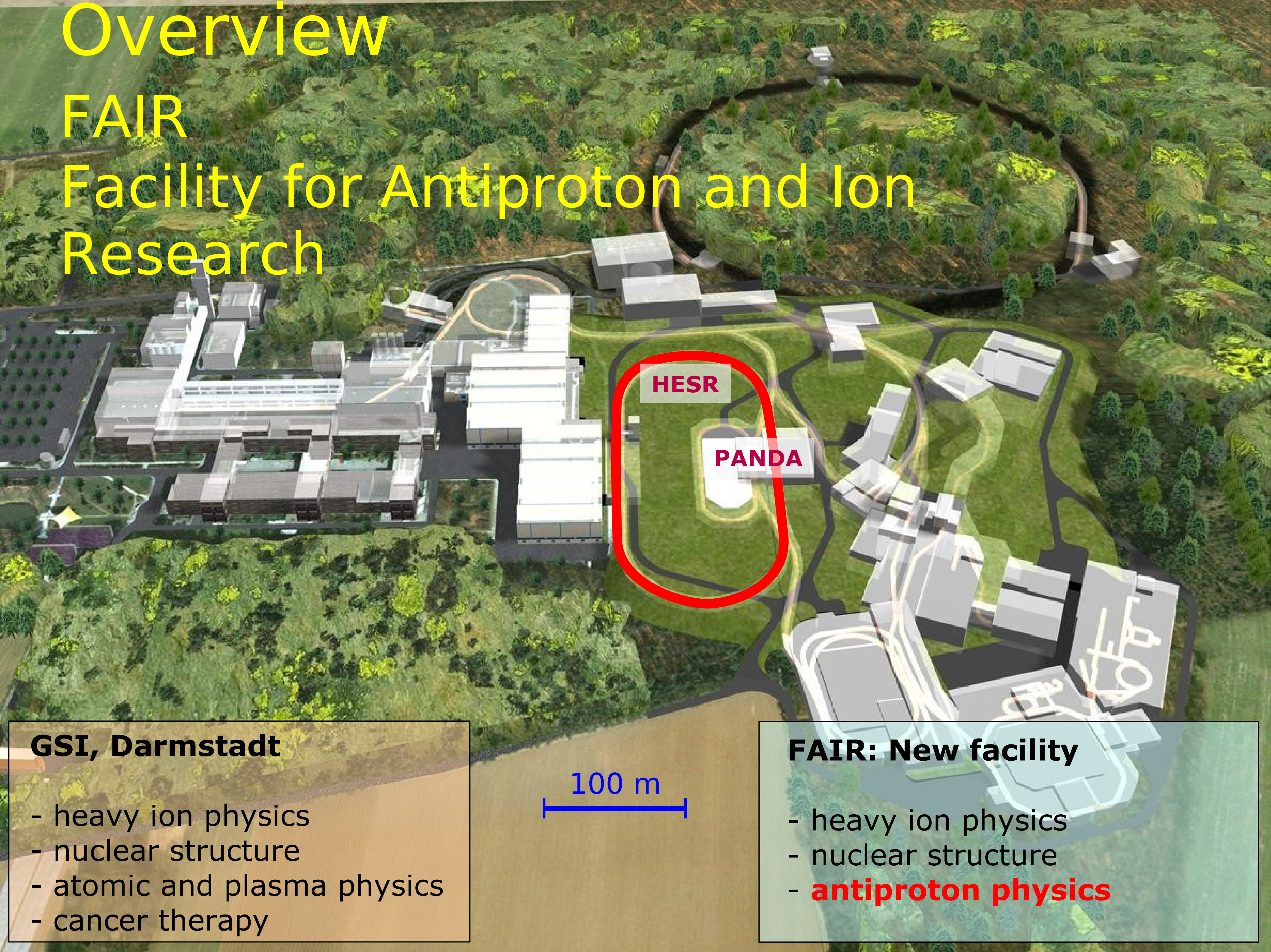
Barrel DIRC

Endcap Disc DIRC

Common developments

Overview

FAIR
Facility for Antiproton and Ion Research



GSI, Darmstadt

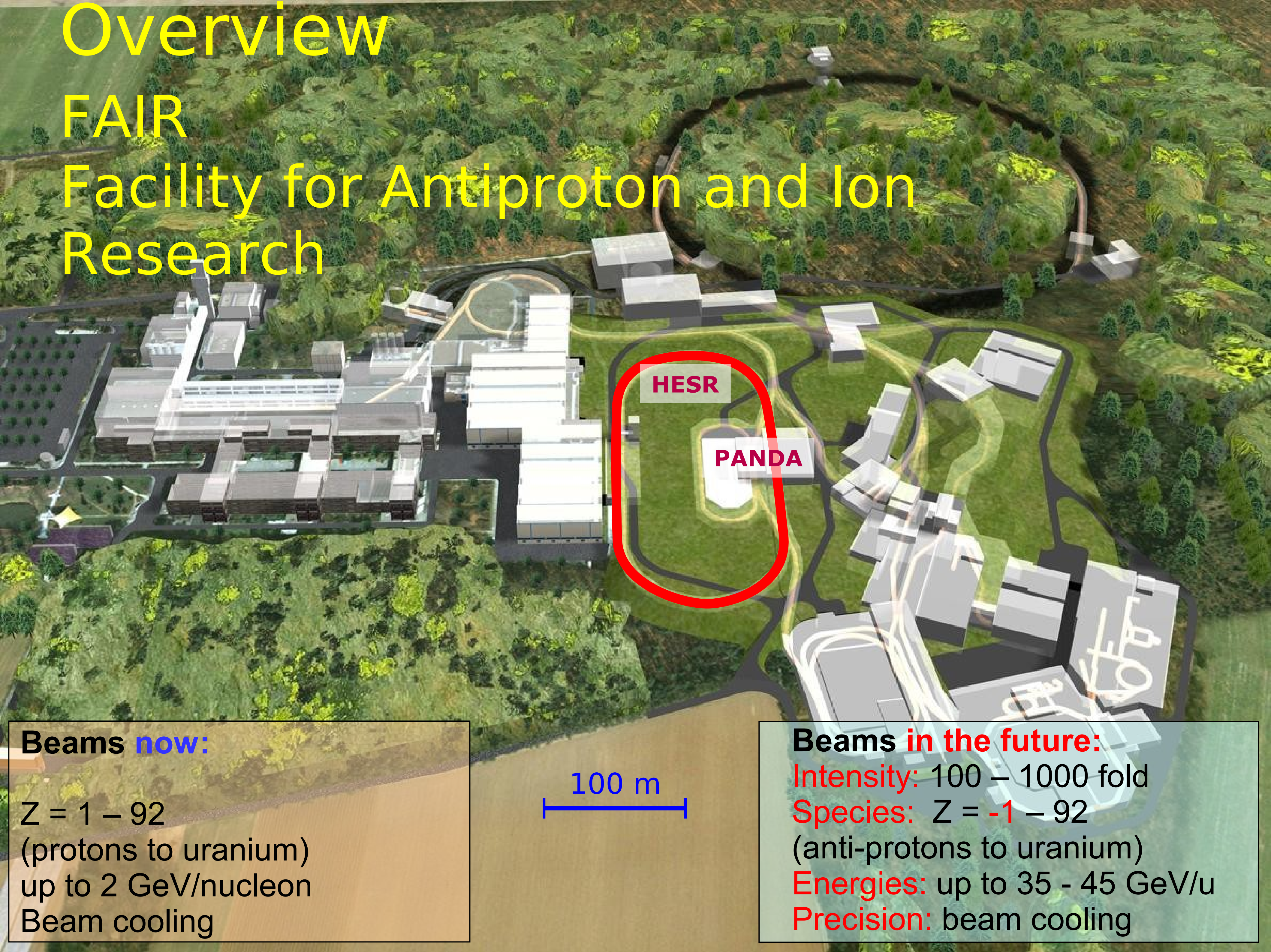
- heavy ion physics
- nuclear structure
- atomic and plasma physics
- cancer therapy

FAIR: New facility

- heavy ion physics
- nuclear structure
- **antiproton physics**

Overview

FAIR
Facility for Antiproton and Ion Research



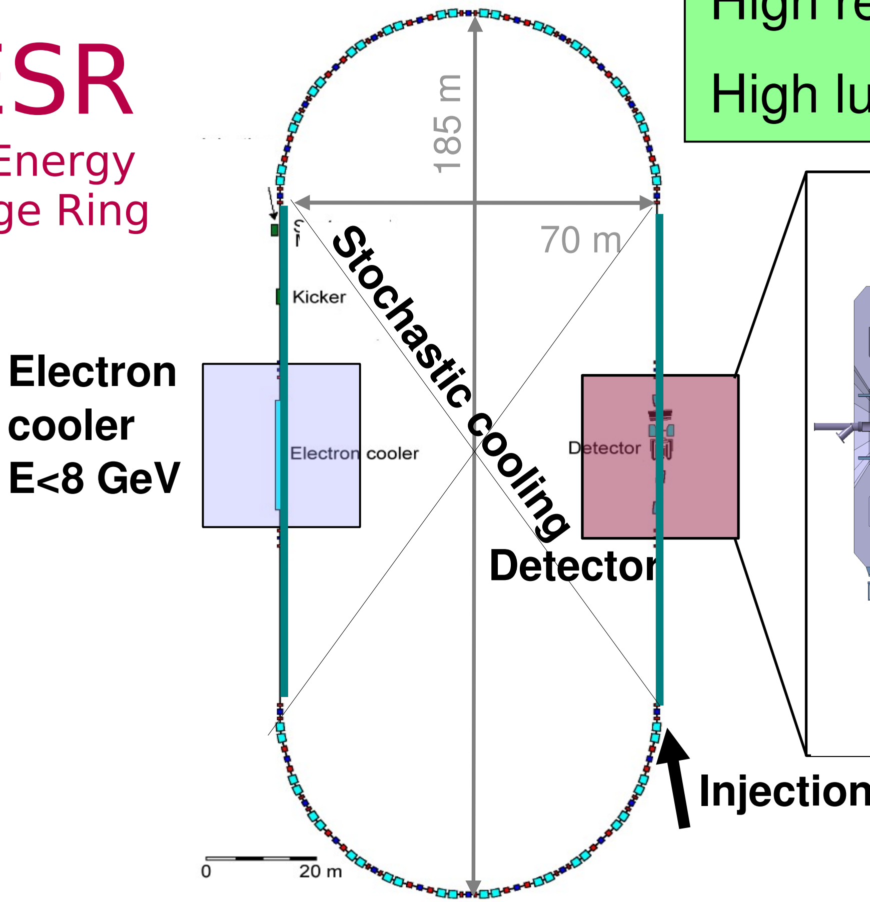
Beams now:

Z = 1 – 92
(protons to uranium)
up to 2 GeV/nucleon
Beam cooling

Beams in the future:
Intensity: 100 – 1000 fold
Species: Z = -1 – 92
(anti-protons to uranium)
Energies: up to 35 - 45 GeV/u
Precision: beam cooling

Overview HESR

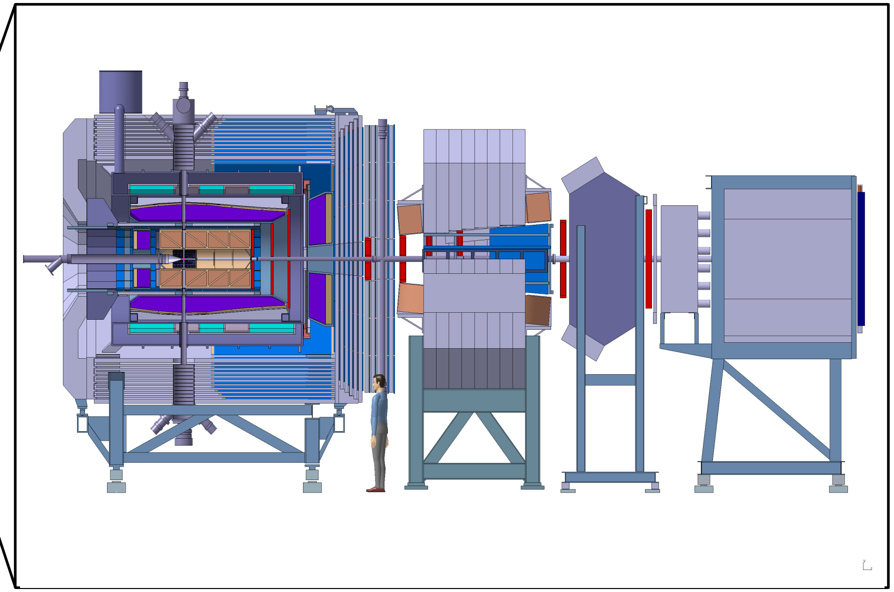
High Energy Storage Ring



Cooling: electron/stochastic

High resol. mode: $\mathcal{L} = 10^{31}\ cm^{-2}\ s^{-1}$ $\delta p/p \sim 10^{-5}$

High lum. mode: $\mathcal{L} = 2 \cdot 10^{32}\ cm^{-2}\ s^{-1}$ $\delta p/p < 10^{-4}$



Characteristics

P_{max} = 15 GeV/c

$\mathcal{L}_{aver.} = 2 \cdot 10^{32}\ cm^{-2}\ s^{-1}$

Ø < 100 µm

$\delta p/p < 10^{-5}$

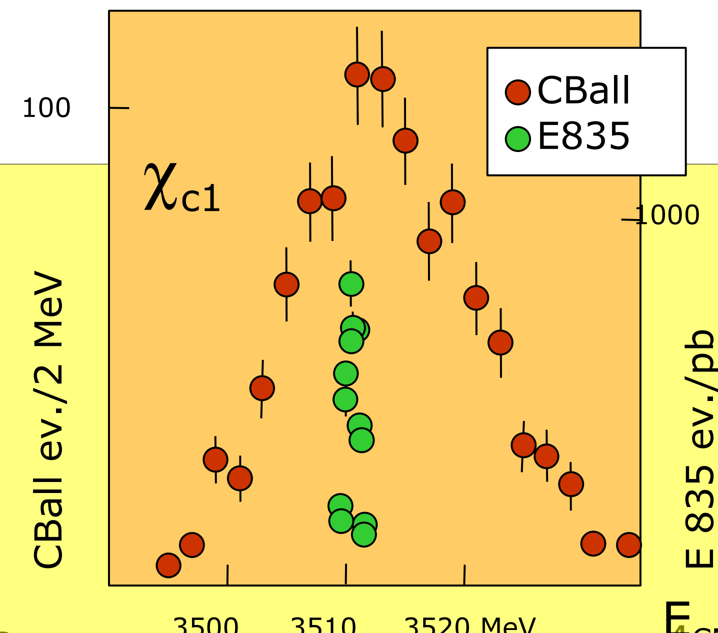
internal target

Resonance scan:

Energy resol. down to ~50 keV

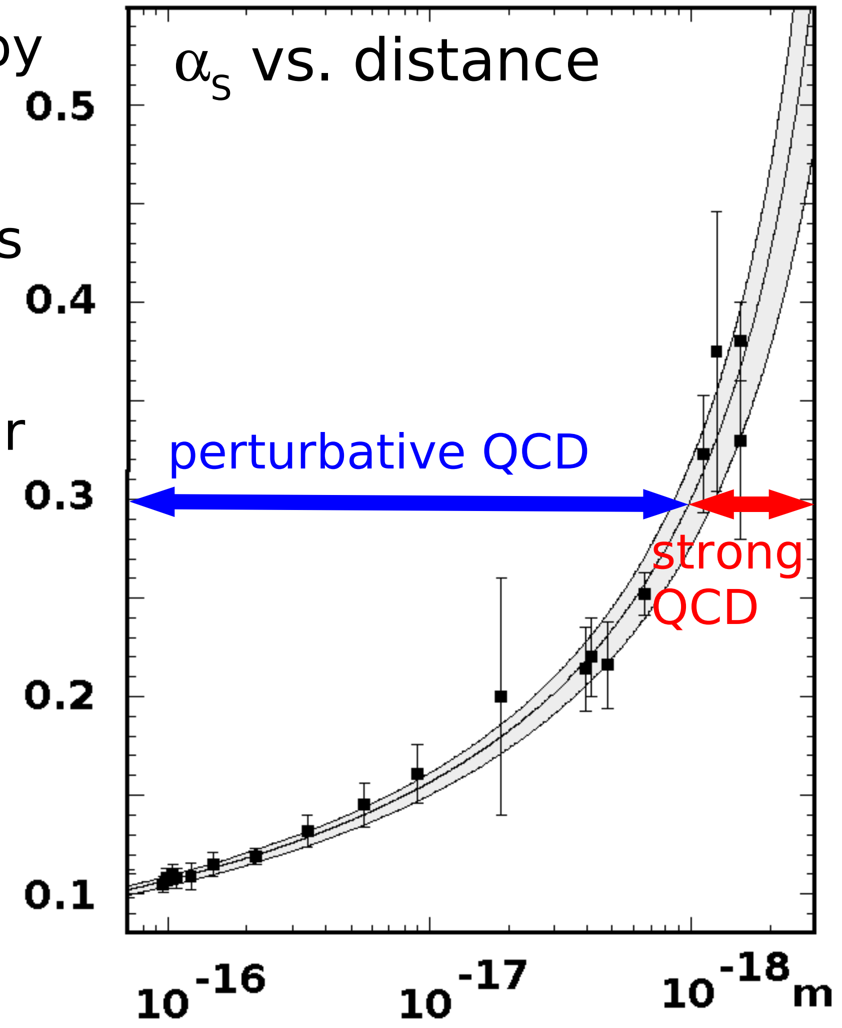
Tune E_{CM} to probe resonance

Get precise mass and width



Overview
Physics topics

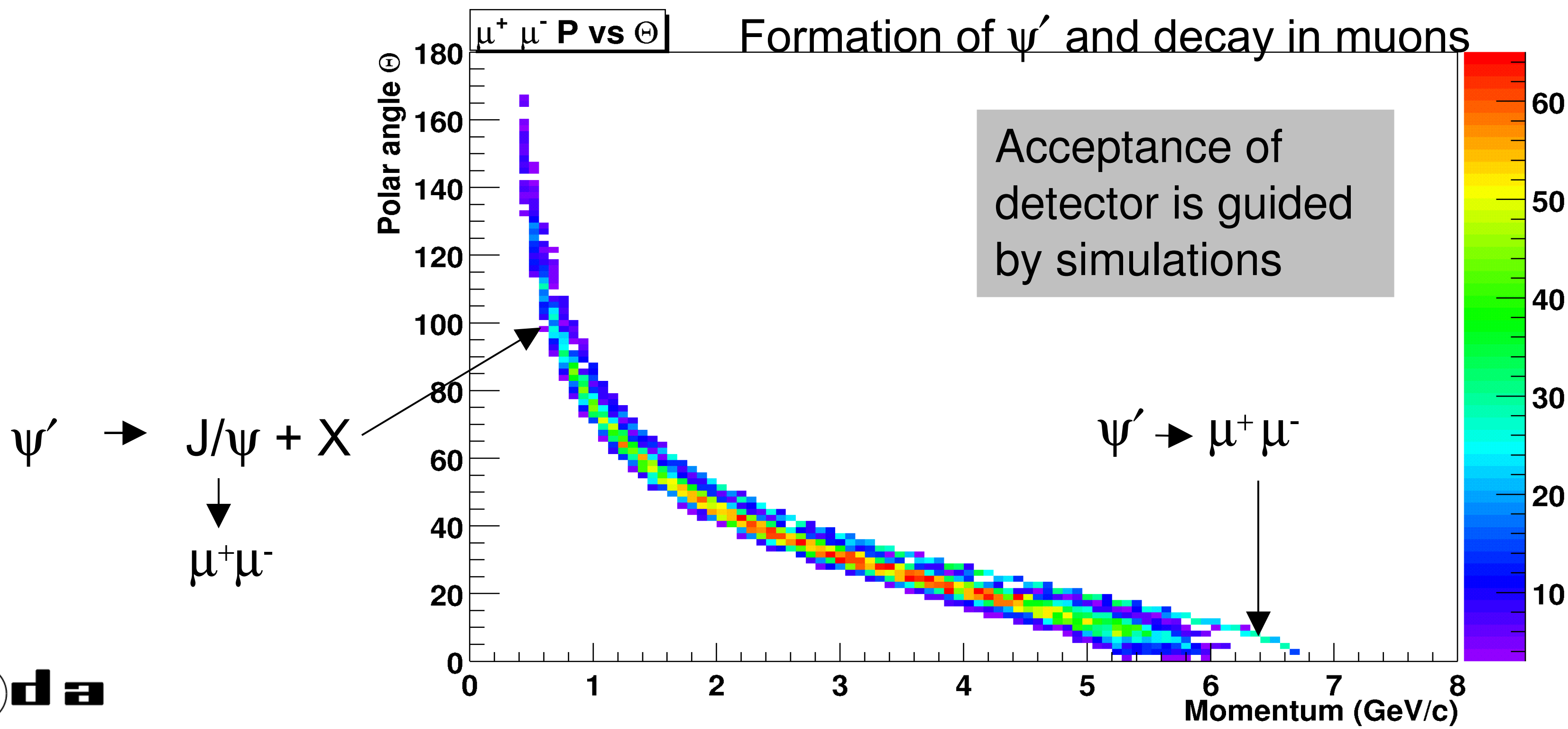
- Charmonium and open charm spectroscopy
  - Confinement
- Search for charmed hybrids and glueballs
  - Formation of color neutral object
- Modification of charmed mesons in nuclear matter
  - Restoration of chiral symmetry
- Hypernuclei
- Nucleon structure



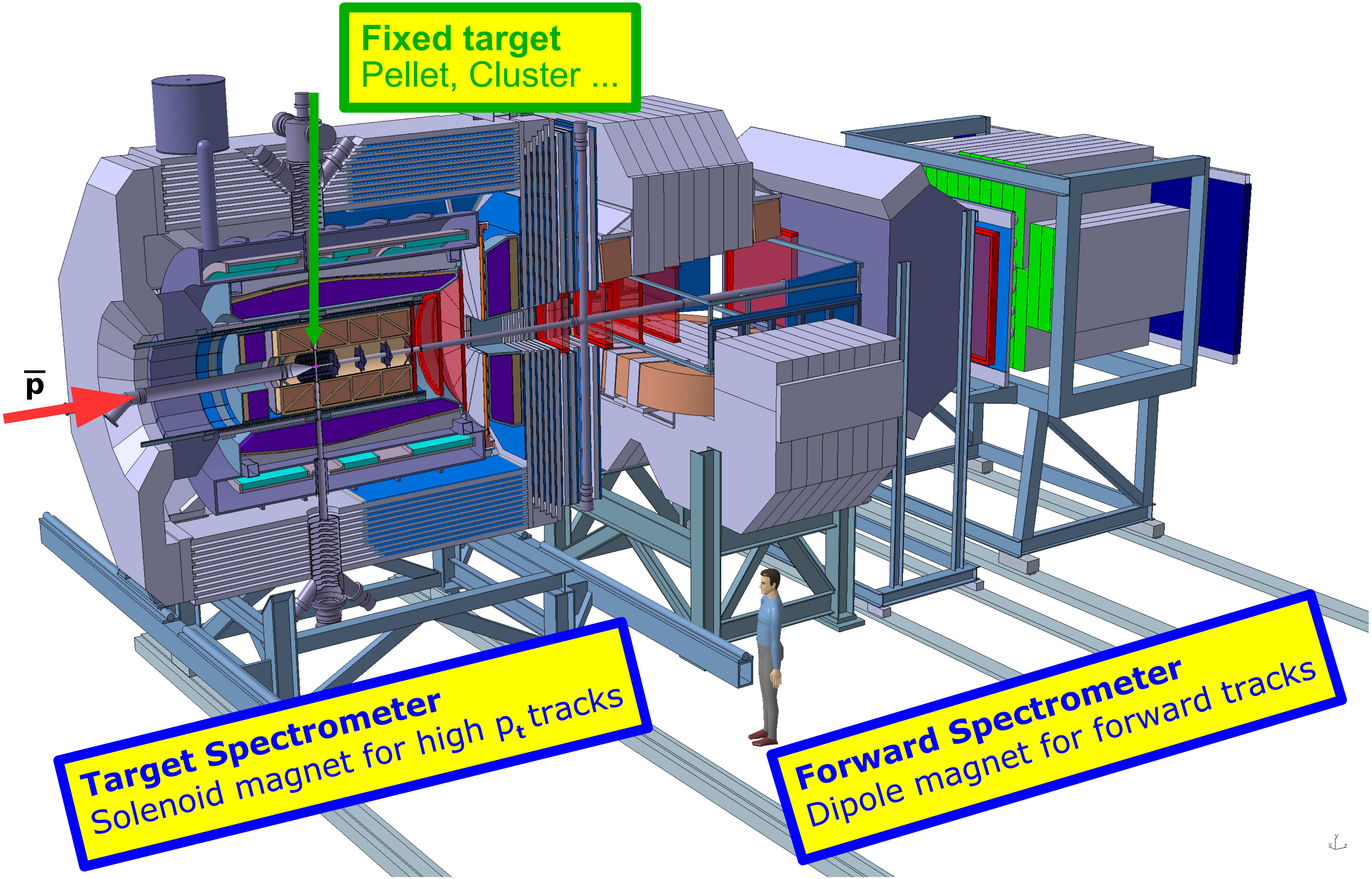
PANDA Detector

Requirements

nearly 4π solid angle for PWA
high rate capability: $2x10^7$ s^{-1} interactions (average)
efficient event selection (triggerless DAQ)
momentum resolution ~1%
vertex info for D, K^0_S, Λ ($c\tau$ = 317 μm for $D^\pm$)
good PID (γ, e, μ, π, K, p)
photon detection 1 MeV – 10 GeV



PANDA Detector



PANDA Detector

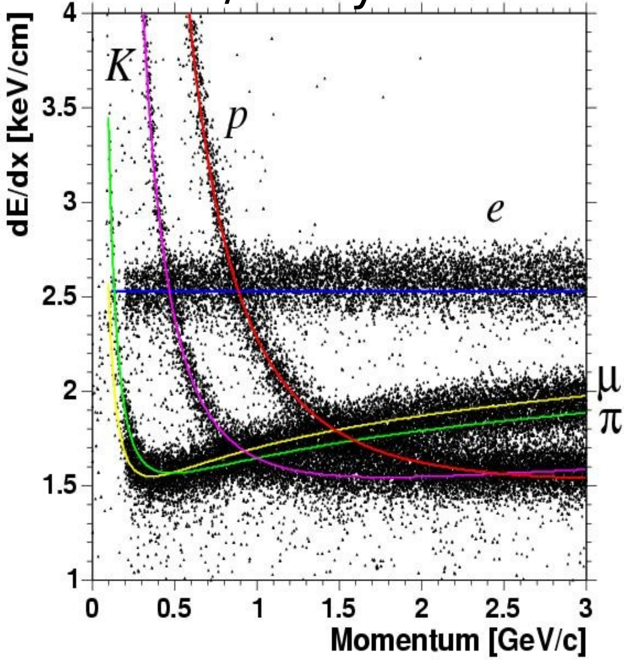
PANDA PID Requirements:

Particle identification essential for PANDA

Momentum range 200 MeV/c – 10 GeV/c

Several methodes for PID needed

dE/dX by TPC



PID Processes:

Cherenkov radiation:

Radiators: quartz

Energy loss: below Cherenkov threshold

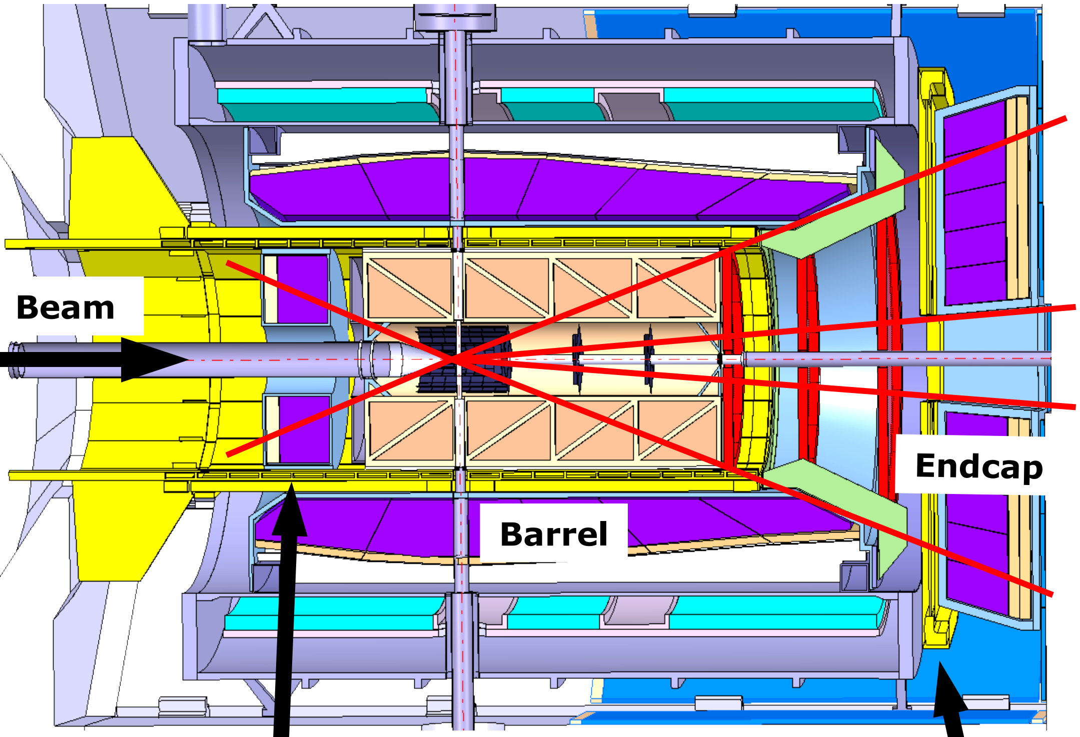
TPC or Straw Tubes

Time of flight

Challenge: no start detector, relative timing

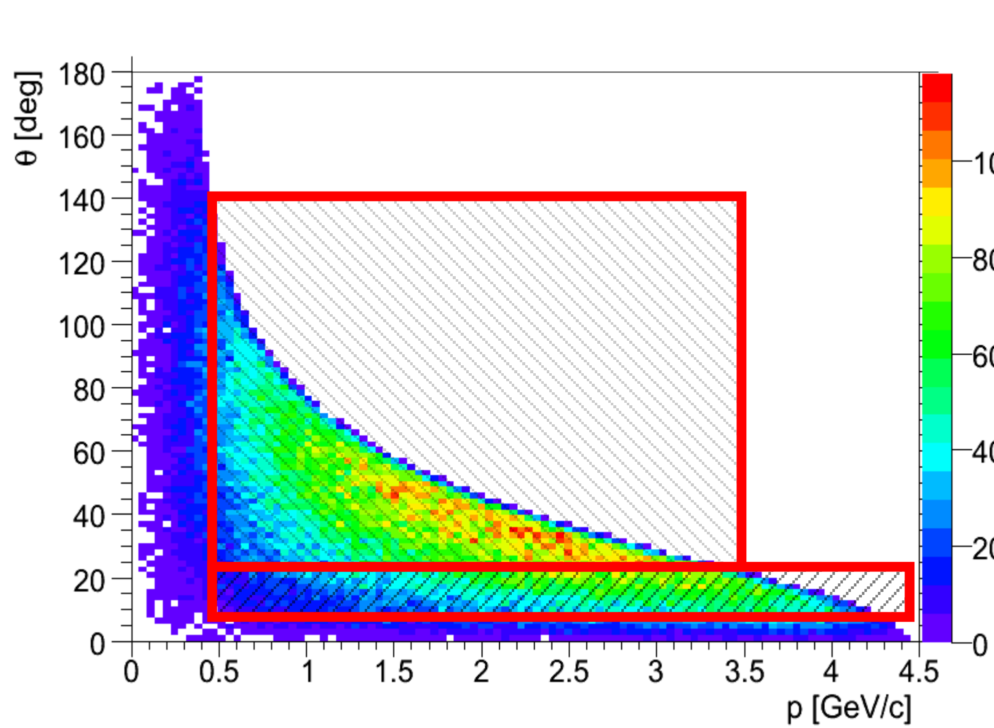
Electromagnetic showers: EMC for e and γ

Cherenkov detectors



barrel DIRC

endcap disc DIRC



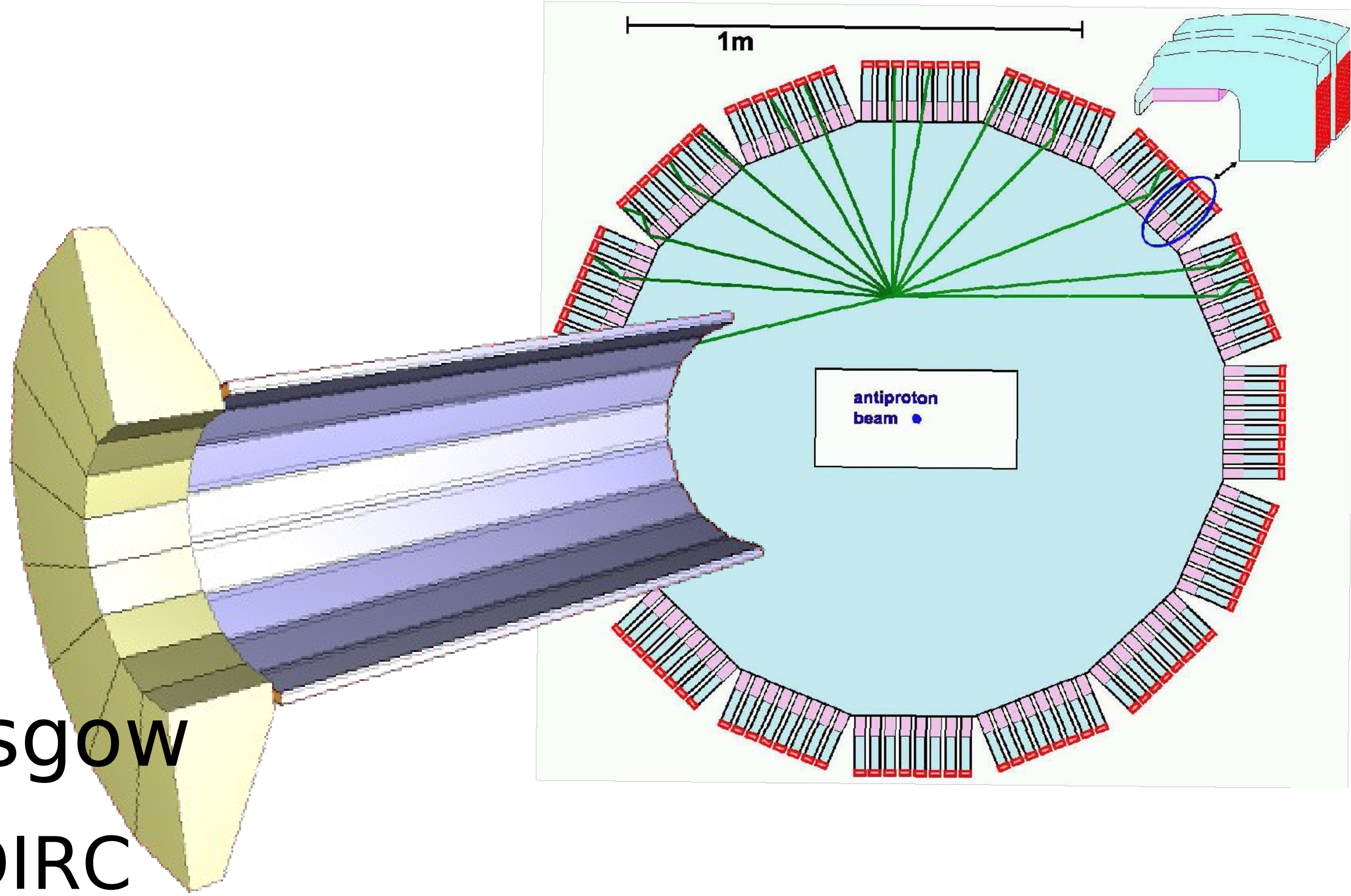
Kaon distribution of the radiative decay

J/ψ -> $K^+K^-\gamma$

(search of glue balls)

Groups

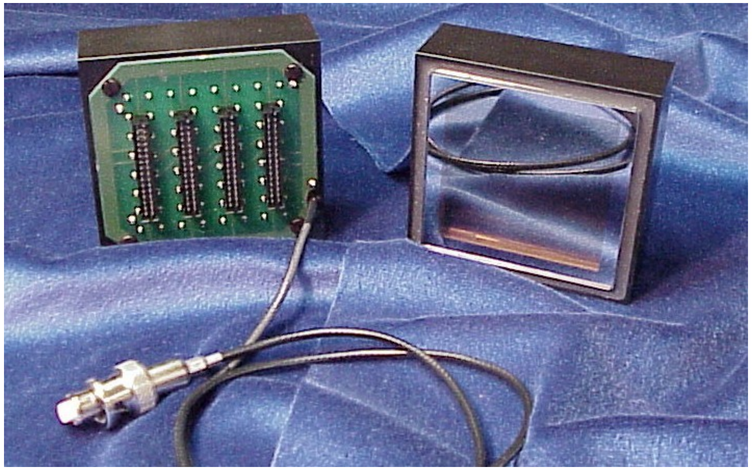
- GSI, Dubna
  Barrel DIRC



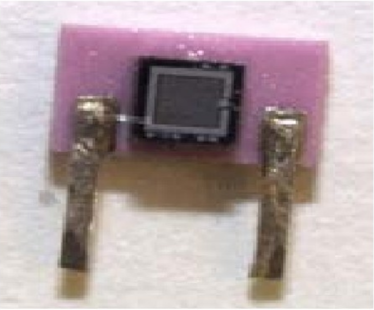
- Giessen, Glasgow
  Endcap Disc DIRC

- Erlangen, Vienna
  MCP-PMT, G-APD

Photonis, Burle-Planacon



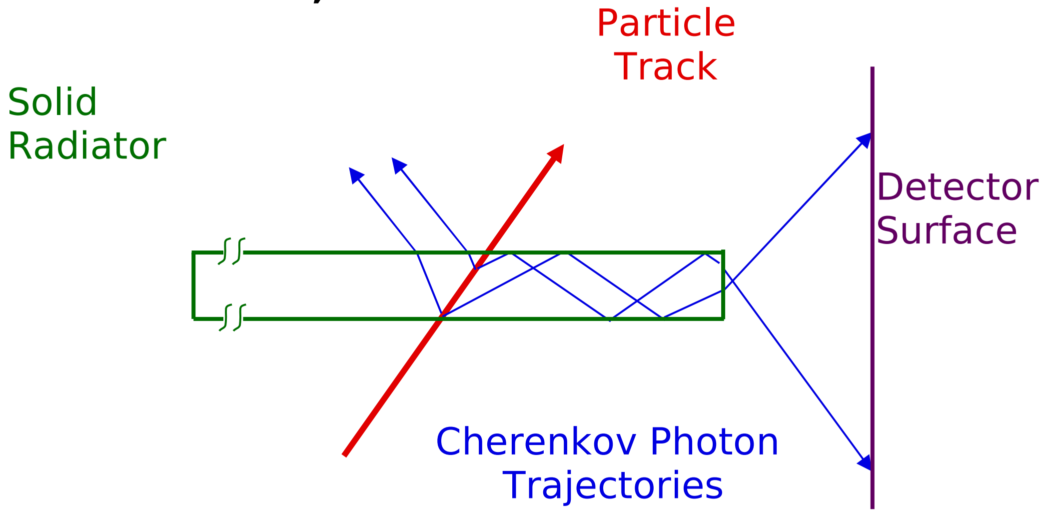
MEPhI/PULSAR SiPM

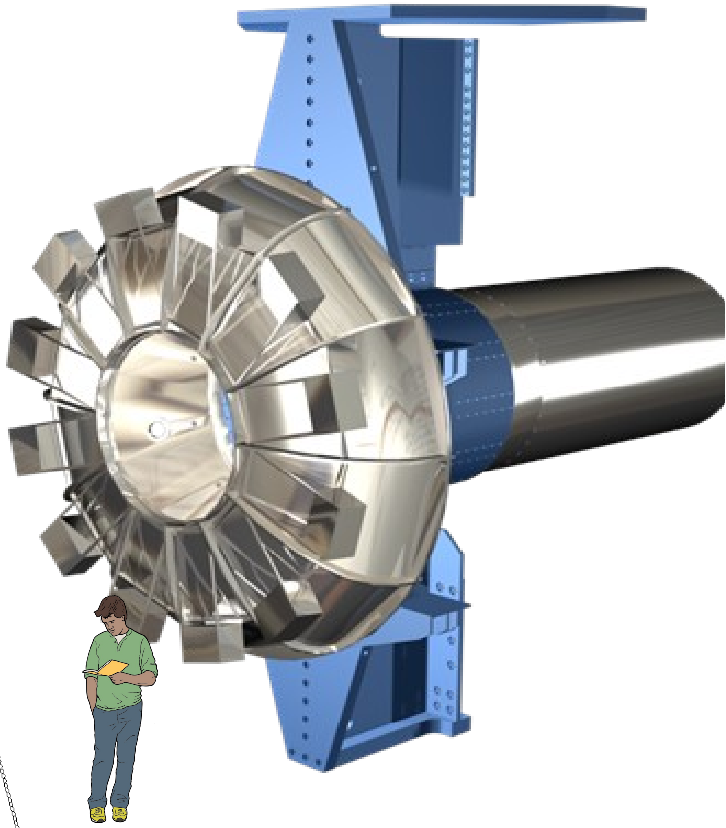


Barrel DIRC

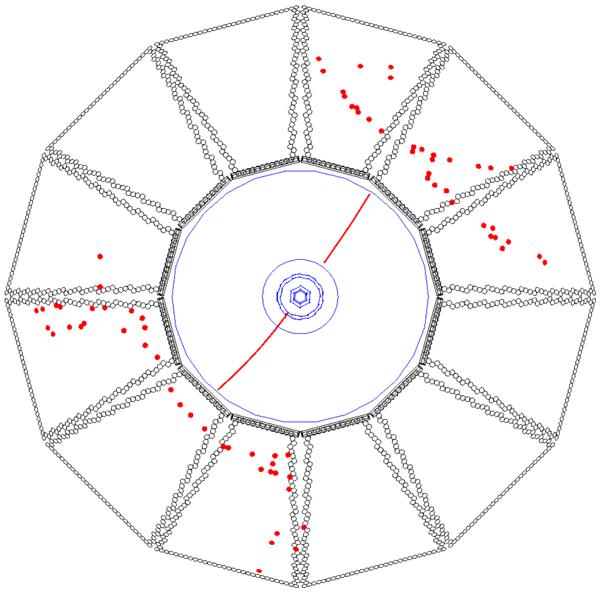
Detection of **I**nternally **R**eflected **C**herenkov light

BaBar DIRC , SLAC

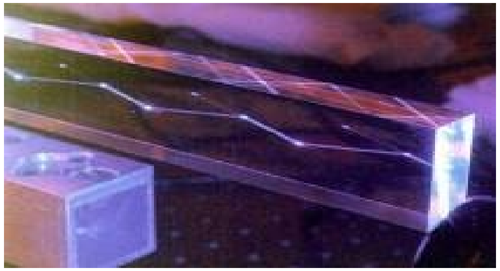




$$\cos(\theta)=\frac{1}{\beta n}$$



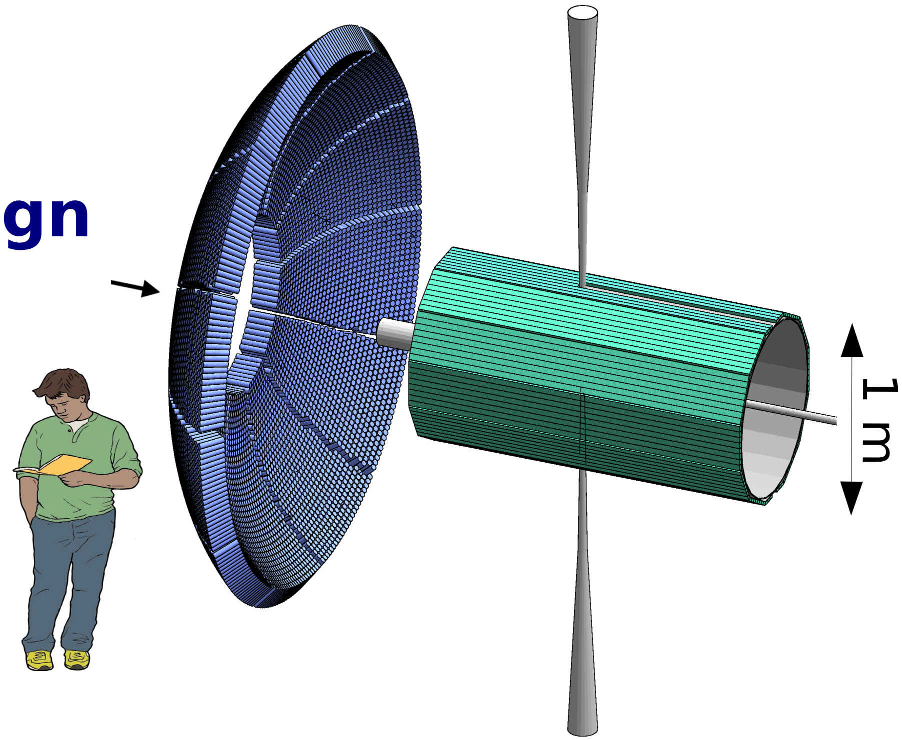
Magnitude of photon angles
in radiator preserved

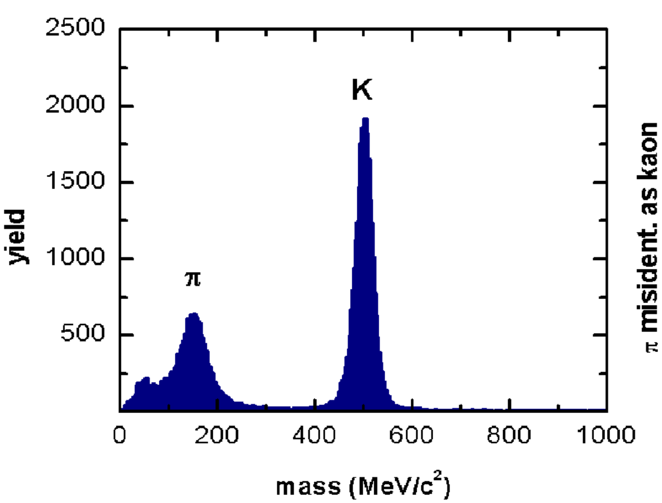


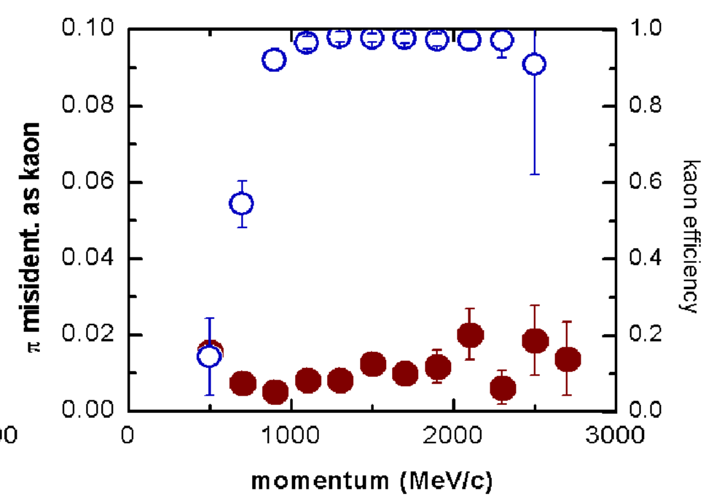
Barrel DIRC

PANDA Barrel DIRC, initial design similar to BaBar

96 Fused silica bars, 2.5m length
Scaled: Water tank & 7000 PMTs







98% kaon efficiency

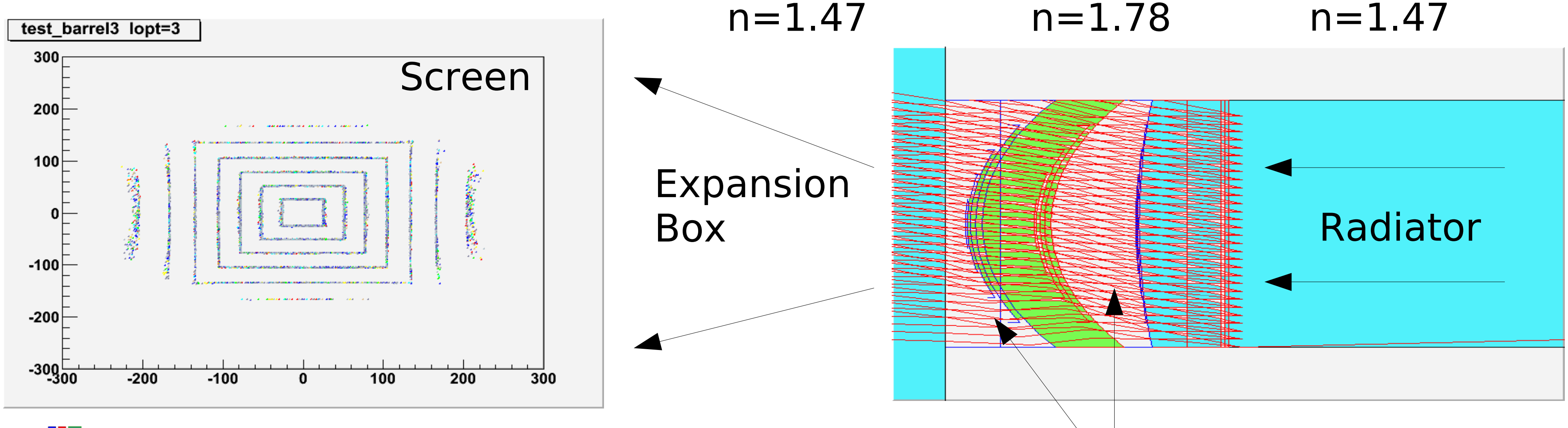
2% pion miss id.

BABAR-DIRC Cherenkov angle resolution: 9.6 mrad per photon → 2.4 mrad per track

Limited in BABAR by:		Could be improved for PANDA via:
▪ size of bar image	~4.1 mrad	▪ focusing optics
▪ size of PMT pixel	~5.5 mrad	▪ smaller pixel size
▪ chromaticity (n=n(λ))	~5.4 mrad	▪ better time resolution
	9.6 mrad	4-5 mrad per photon → 1.5–2 mrad per track

PANDA DIRC Design

Lens design by
ZEMAX optical software



Current design of Barrel DIRC

More compact, faster, focusing optics

96 radiator bars, synthetic fused silica
17mm (T) × 33mm (W) × 2500mm (L)

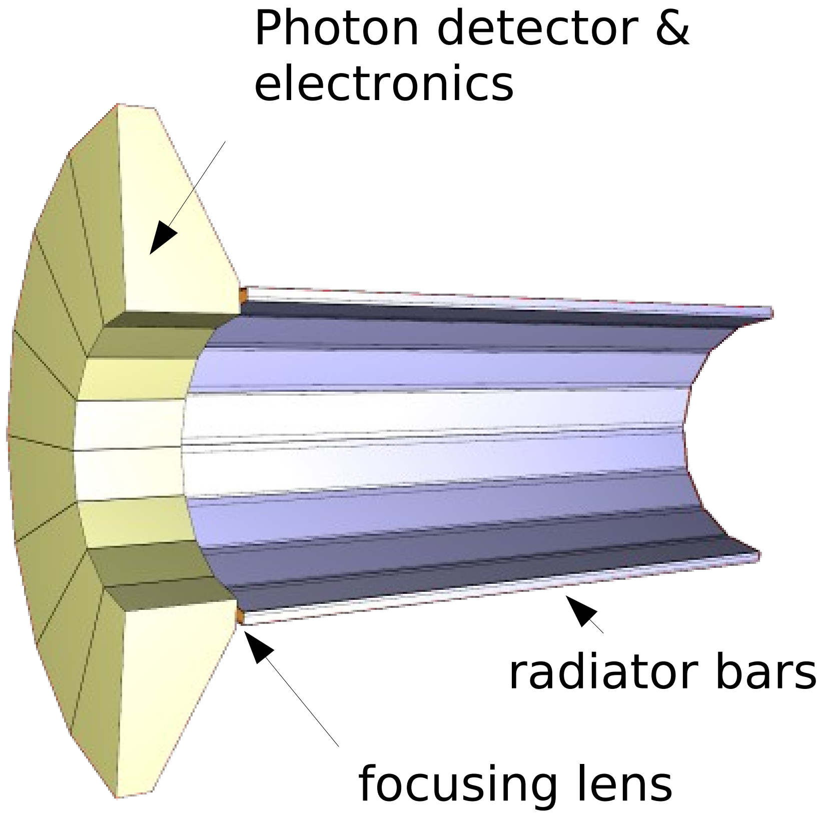
Focusing optics: lens system

Compact photon detector: array of
Burle Planacon MCP-PMT
G-APD
total 7000-10000 channels.

Poster, Johann Marton

Fast photon detection: MCP-PMT
fast TDC/Time Over Threshold electronics

→ 100-200 ps timing.



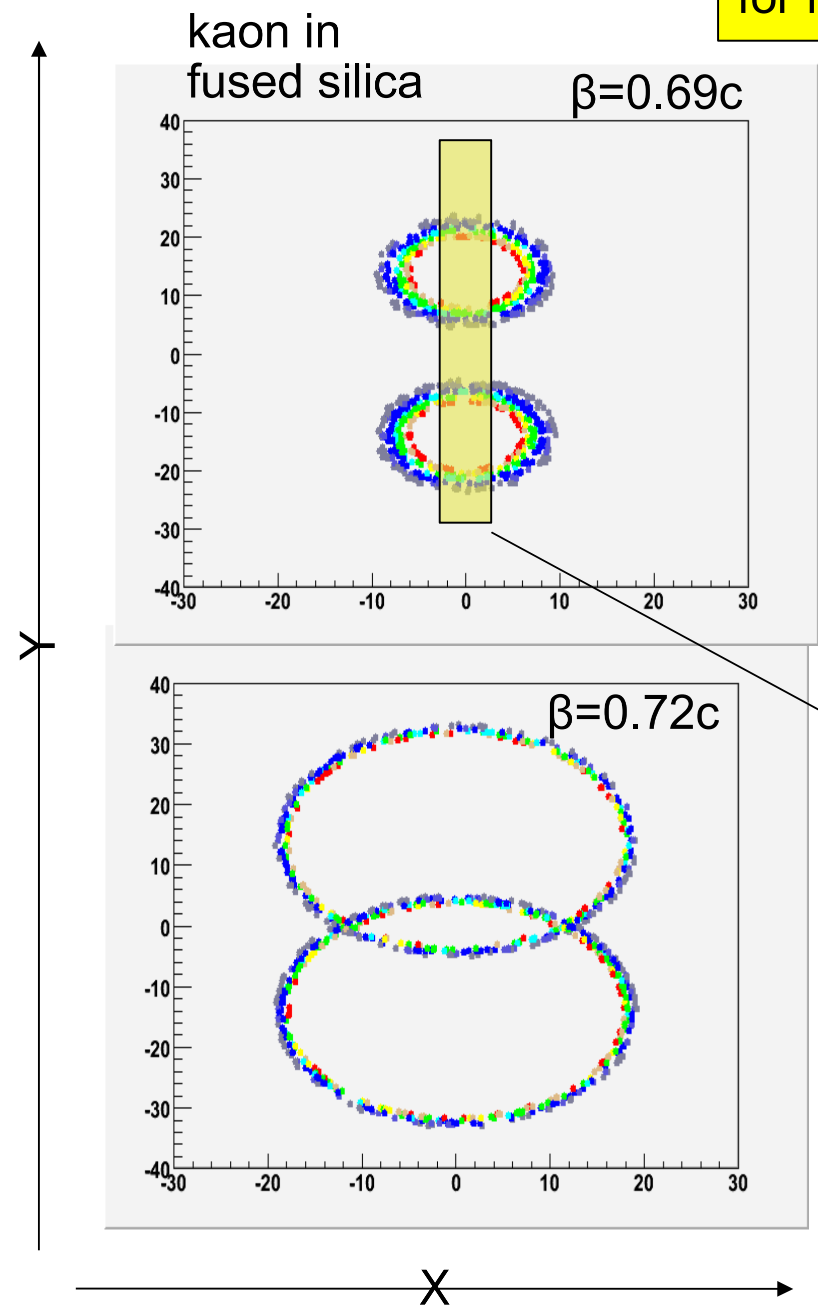
Poster, Jochen Schwiening

Still investigating several design options:

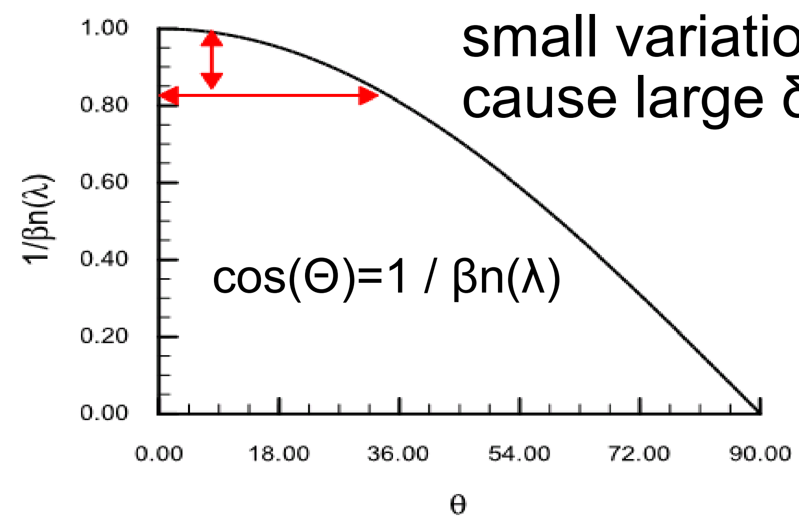
mirror focusing, radiator plates, photon detection outside magnetic field

3D-DIRC

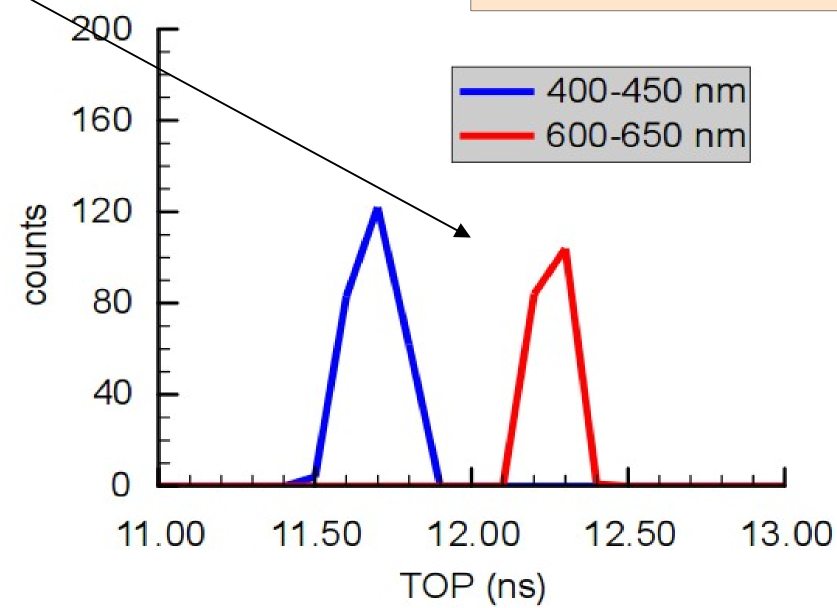
Time of Propagation measurement better than 100-200 ps
allows to partially correct dispersion
for high and low momenta → x,y,t → 3D-DIRC



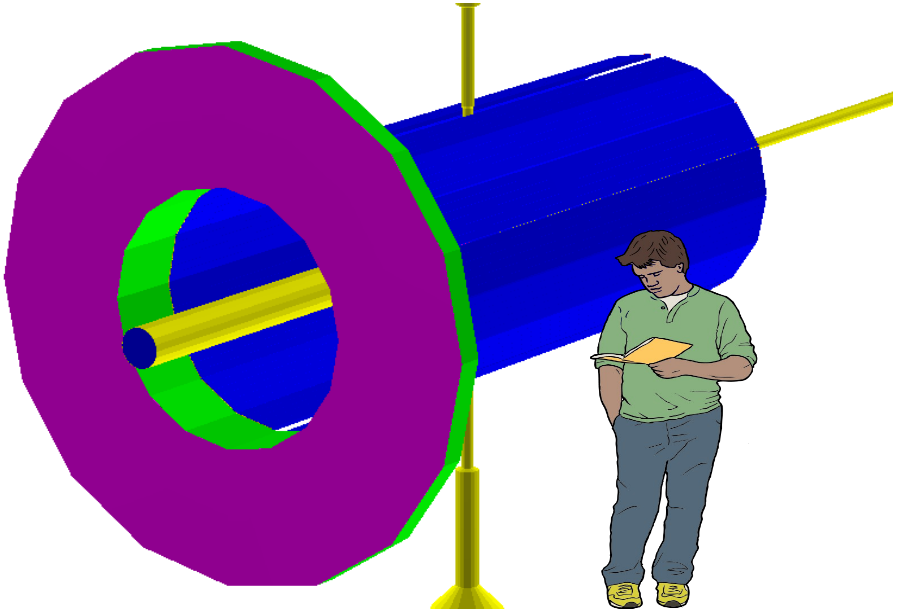
close to threshold:
small variations in n(λ)
cause large δθ

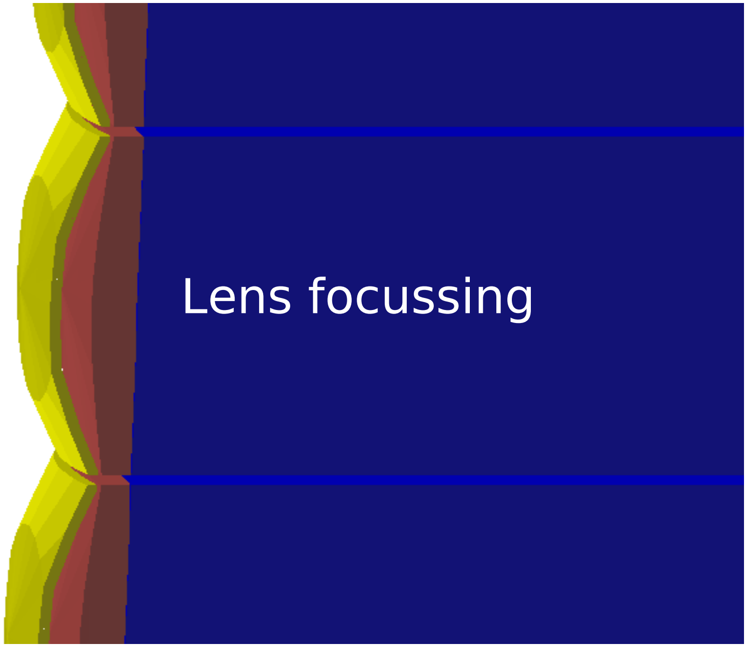


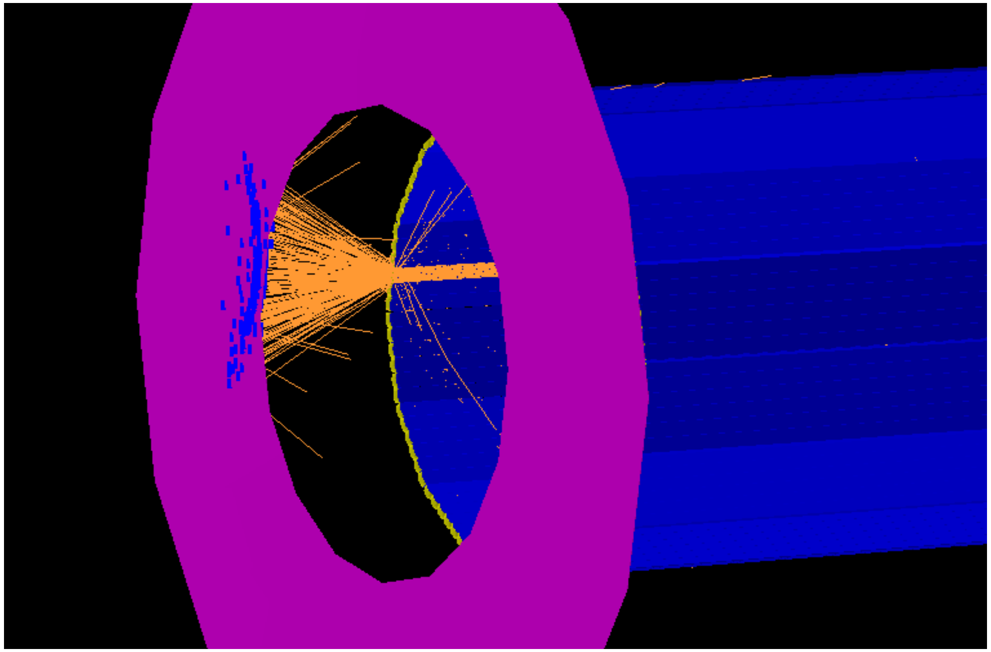
software dispersion correction



Simulations in PandaRoot





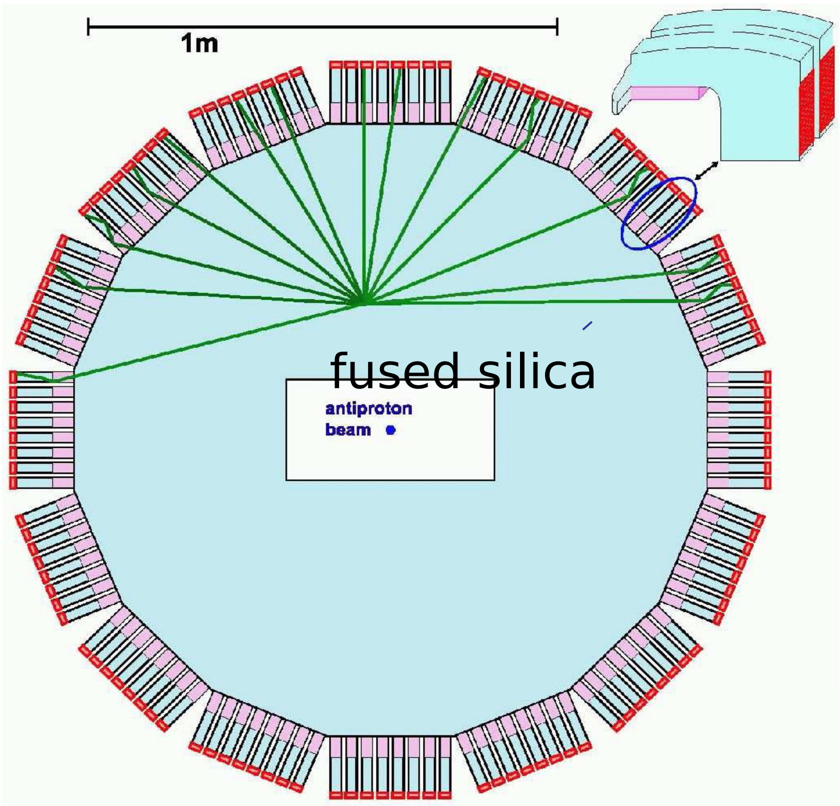


Poster, Dipanwita Dutta

Design is being optimized

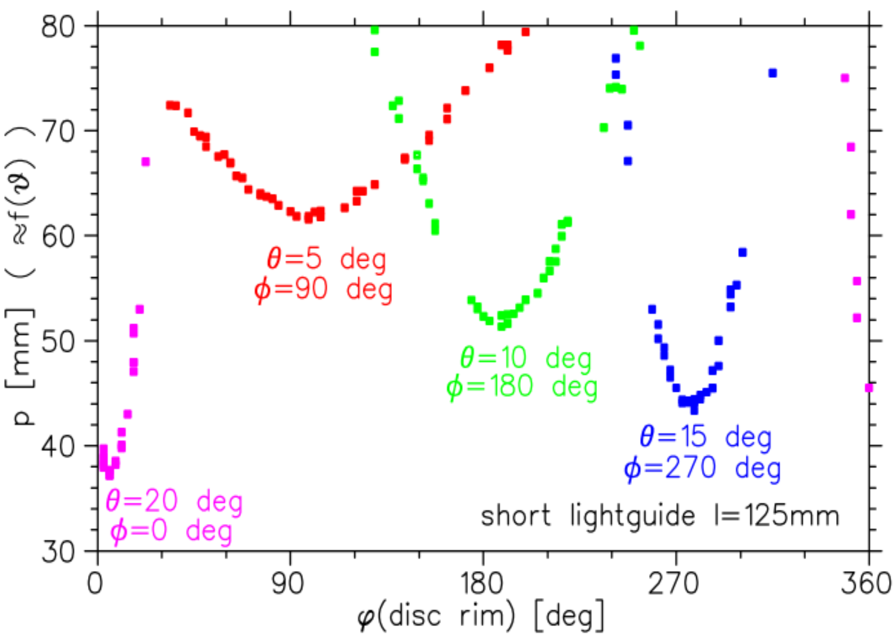
Fast reconstruction algorithm being developed

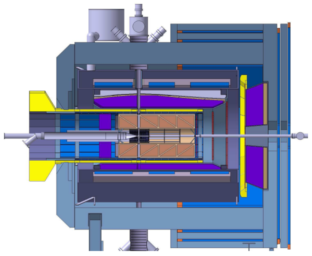
Endcap Dirc – Focusing Lightguide Option

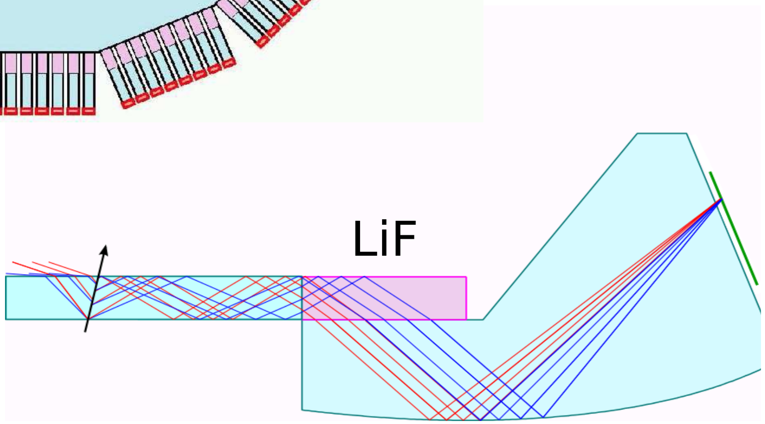


LiF for dispersion correction
has smaller |dn/dλ| than SiO_2

focussing better than 1mm
flat focal plane

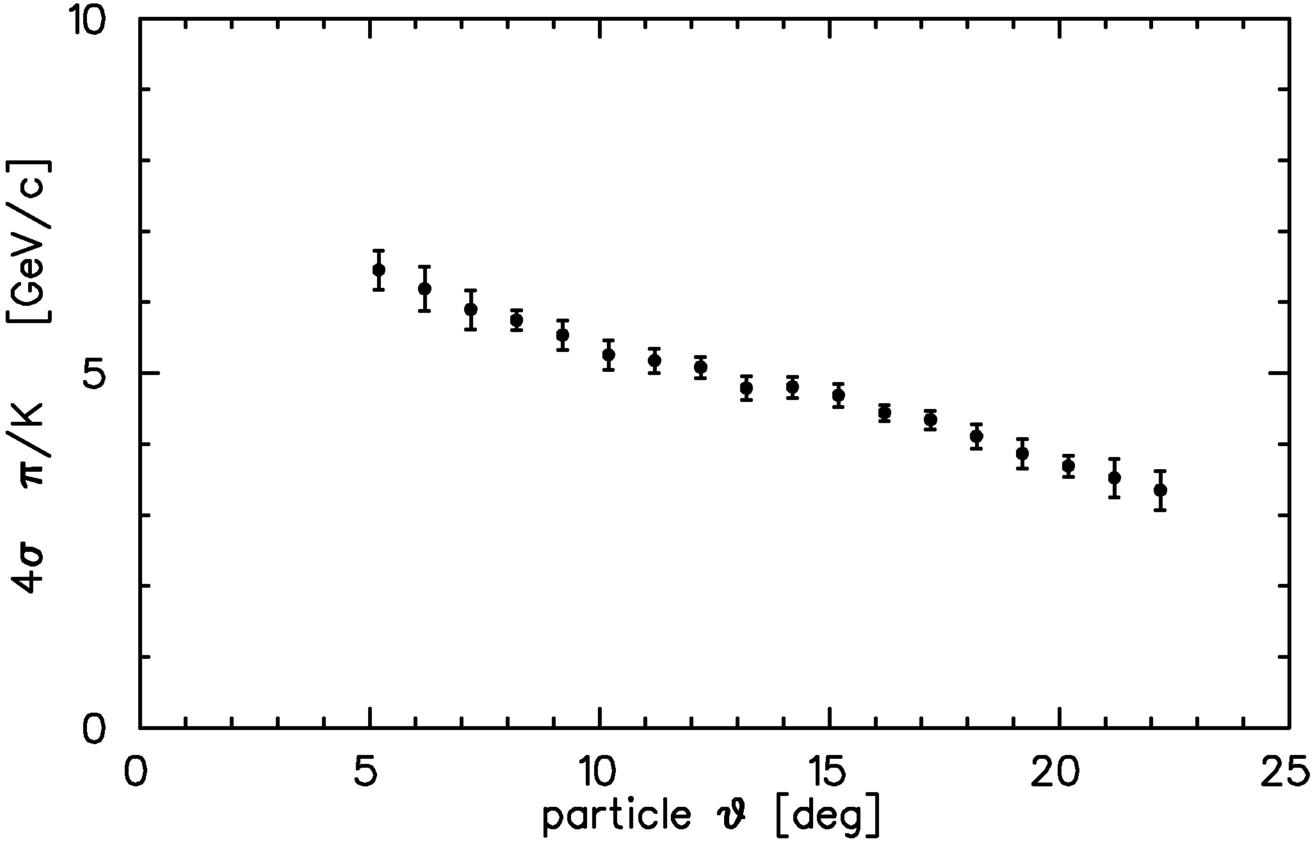






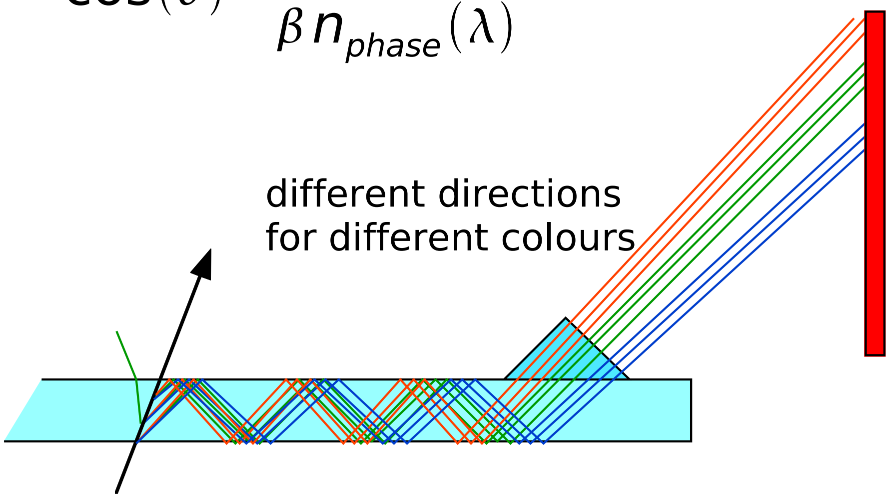
hardware dispersion correction

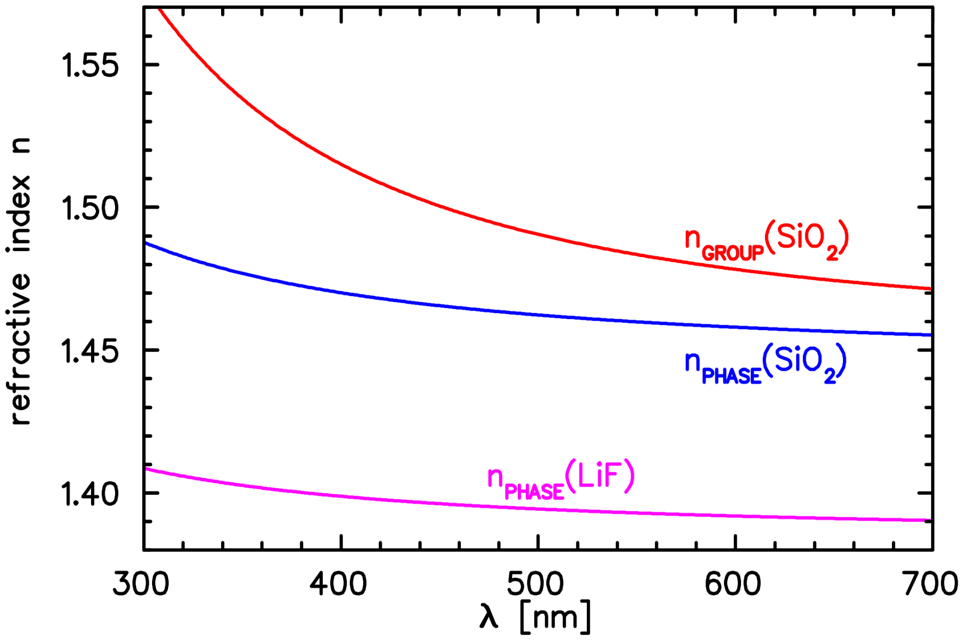
Endcap Disc DIRC - resolution



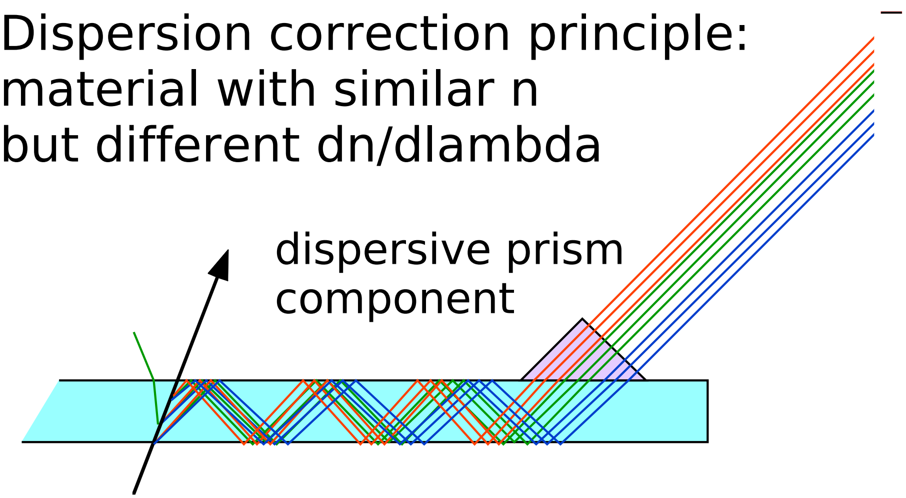
Cherenkov Radiation Dispersion

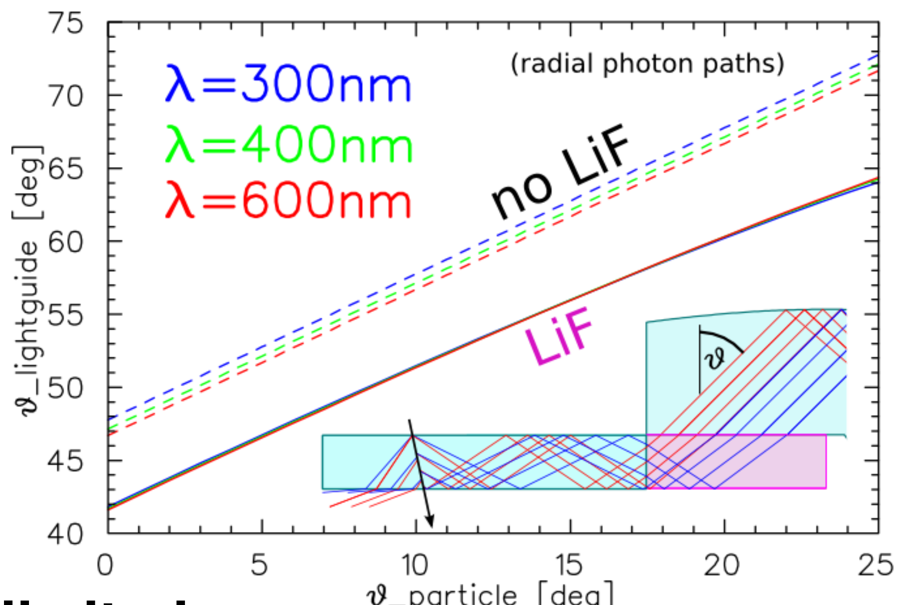
$$\cos(\theta)=\frac{1}{\beta\, n_{phase}(\lambda)}$$





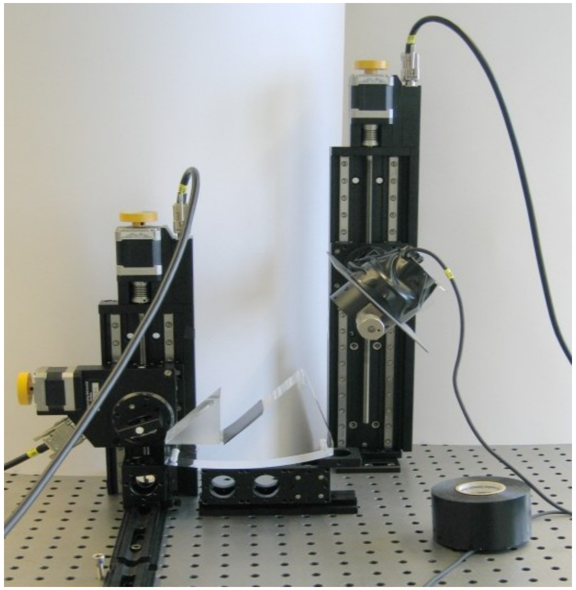
Dispersion correction principle:
material with similar n
but different dn/dlambda

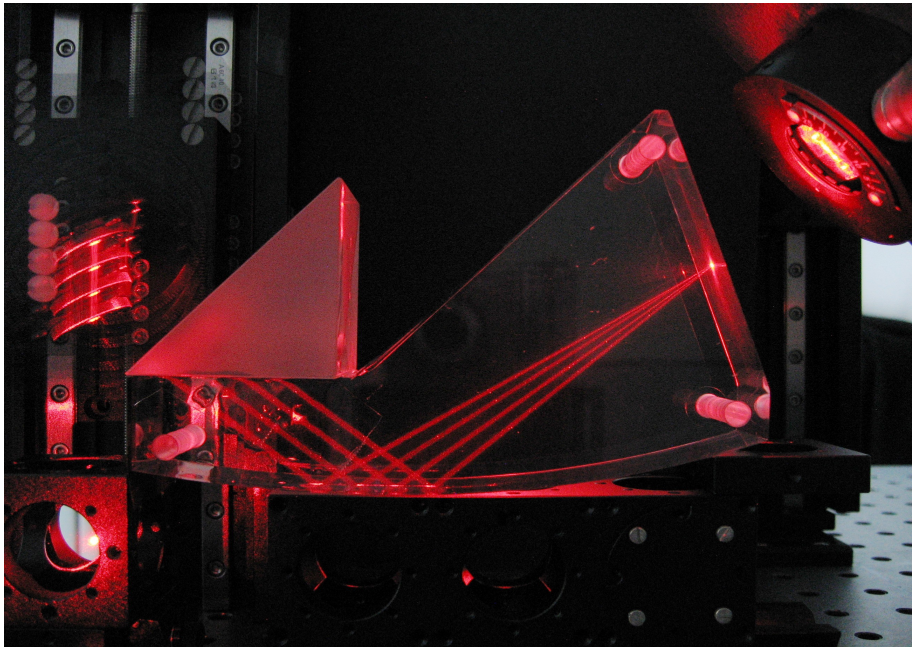


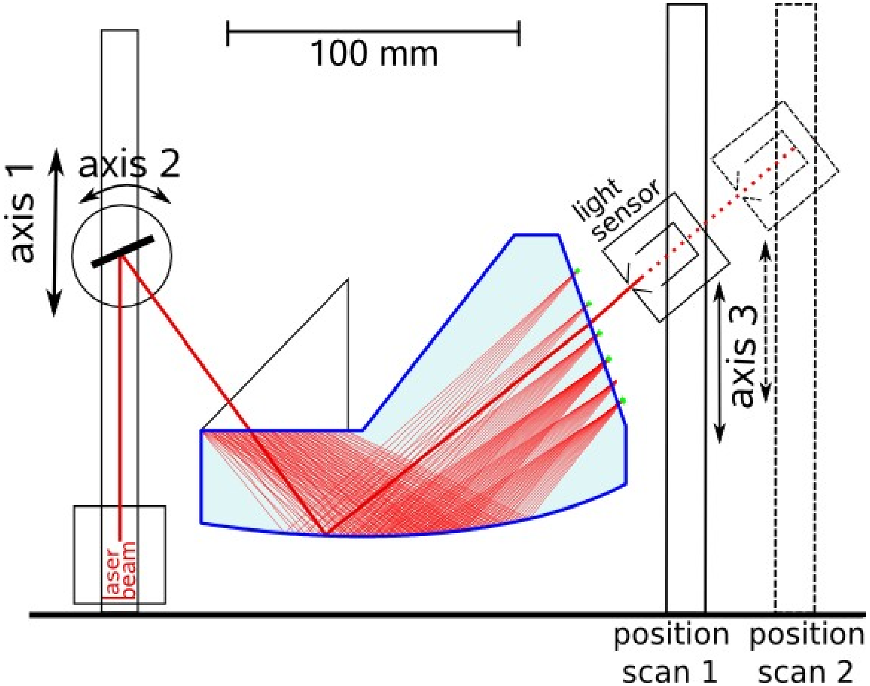


N.B. choice of corrector materials rather limited

Focussing lightguide

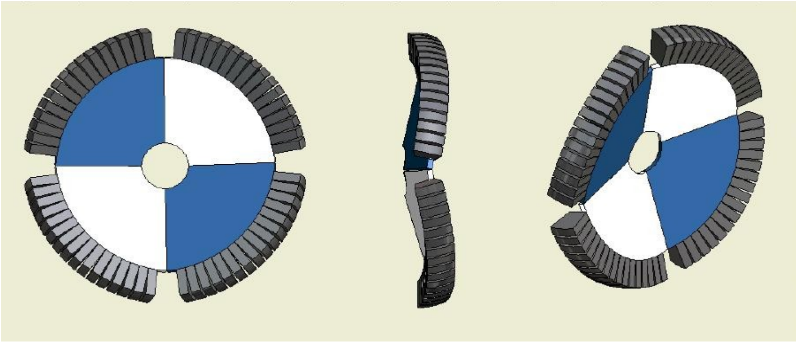






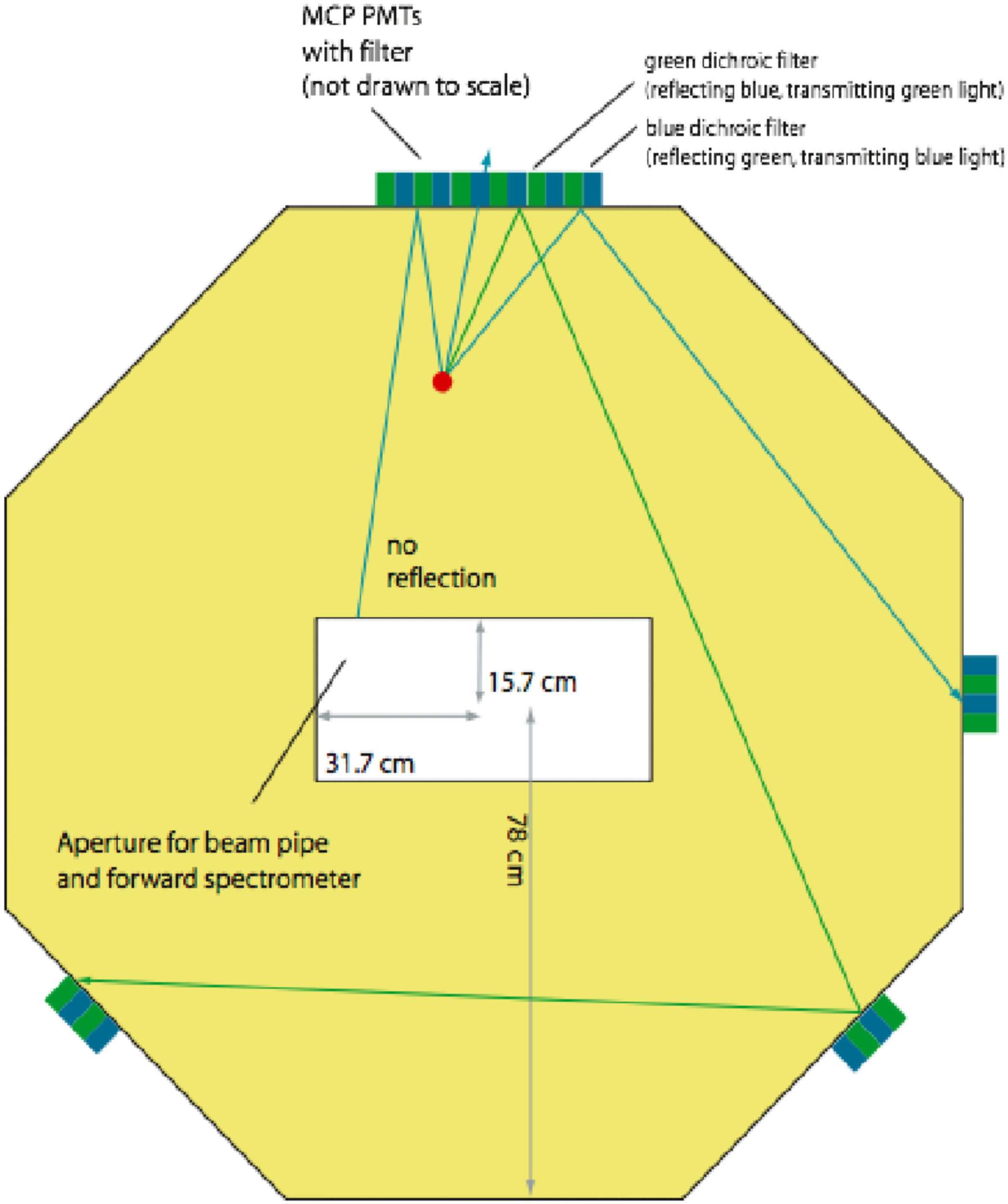
first demonstrator setup
to verify proper optics
of workshop machined
Focusing Light Guides

CEARA



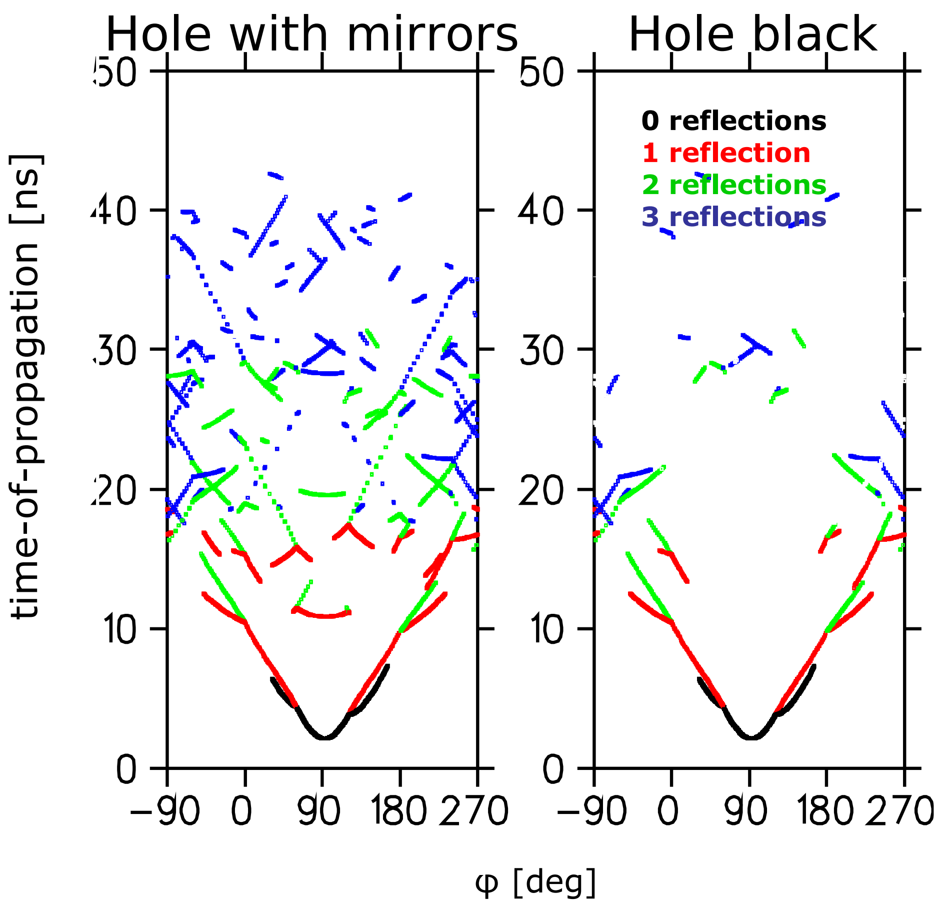
Poster, Klaus Föhl
Poster, Adrian Schmidt

Endap DIRC – Time Of Propagation option



dichroic mirrors as colour filters

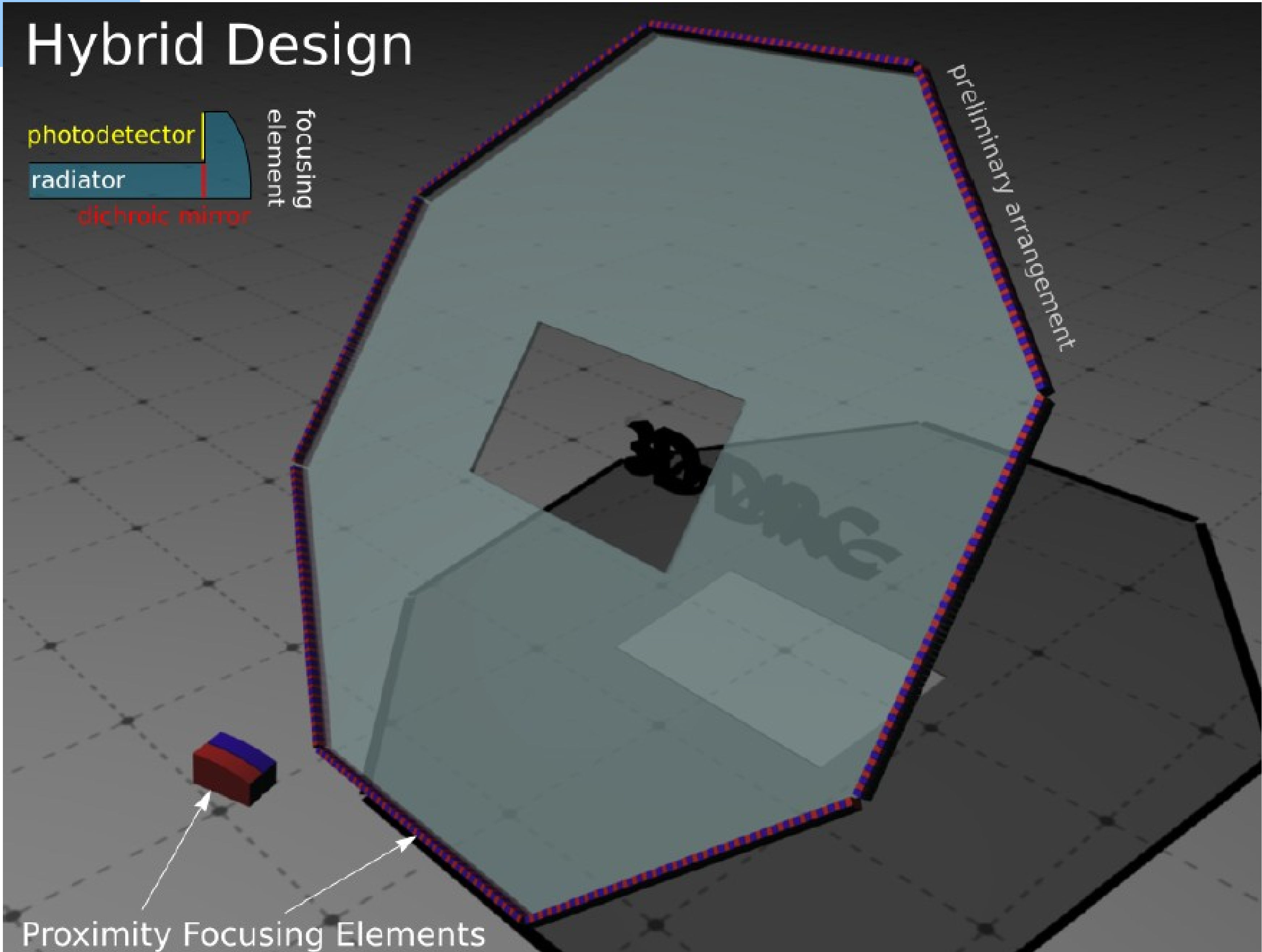
two wavelength bands
dispersion correction
different and longer path lengths



single photon resolution σ_t~30-50ps required
missing start detector: relative timing between photons

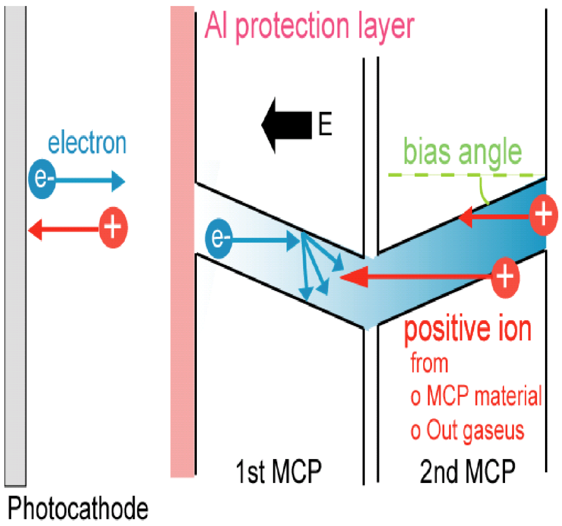
Hybrid DIRC
combines strength of focussing option with ToP option

Helps to reject photons from knock on electrons by angular measurement.



The photon detection device

Multi Channel Plate - PMT



Ageing: typically 1C/cm^2 -> 30% loss of QE

PANDA:

Barrel	0.8 C/cm2/yr
Focussing	3.8 C/cm2/yr
TOP	9.6 C/cm2/yr

ongoing developments
close cooperation with companies

Talk, Albert Lehmann

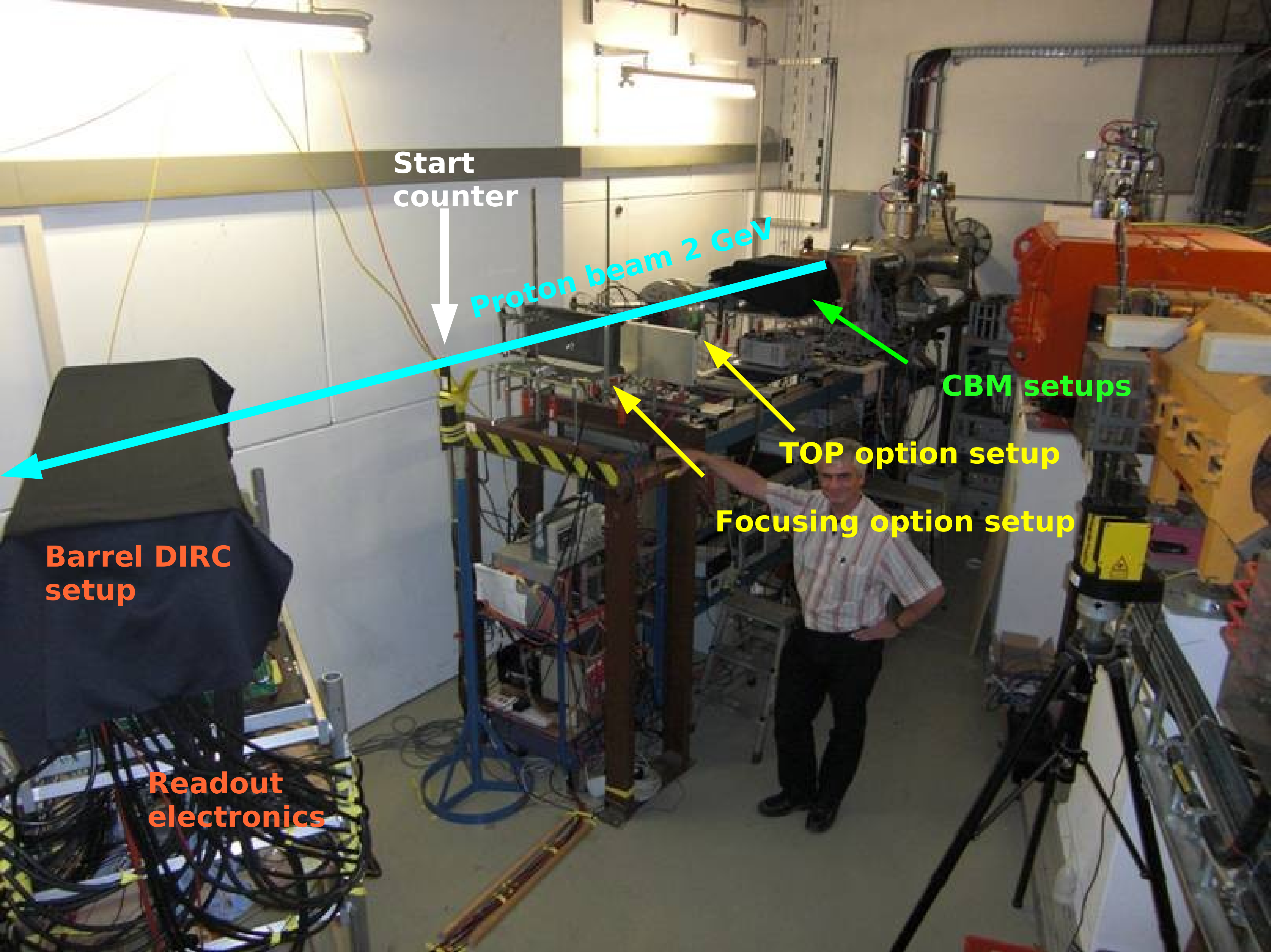
Common developments for endcap and barrel

- Radiator
  - Radiation hardness — Poster, Matthias Hoek
  - Shape, Surface quality — Poster, Jochen Schwiening
- Photon detectors
  - Multi-Channel-Plate MCPs — Talk, Albert Lehmann
  - G-APD — Poster, Johann Marton
- Test experiments

Poster, Jochen Schwiening

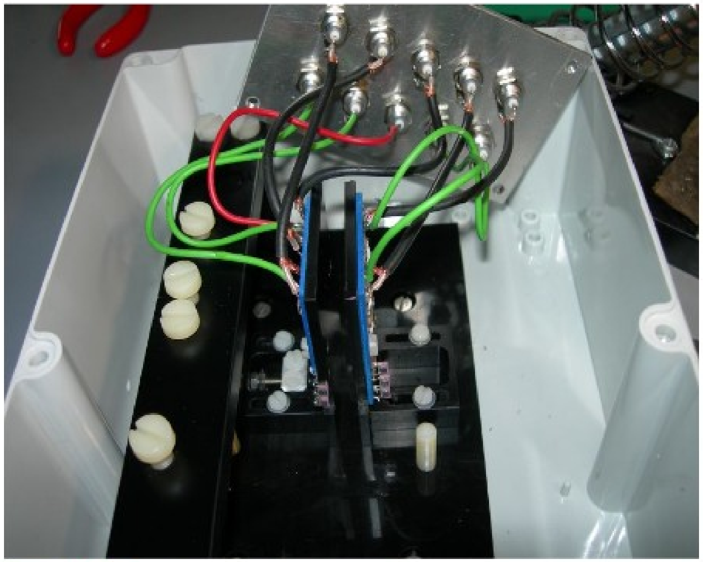
Poster, Euan Cowie

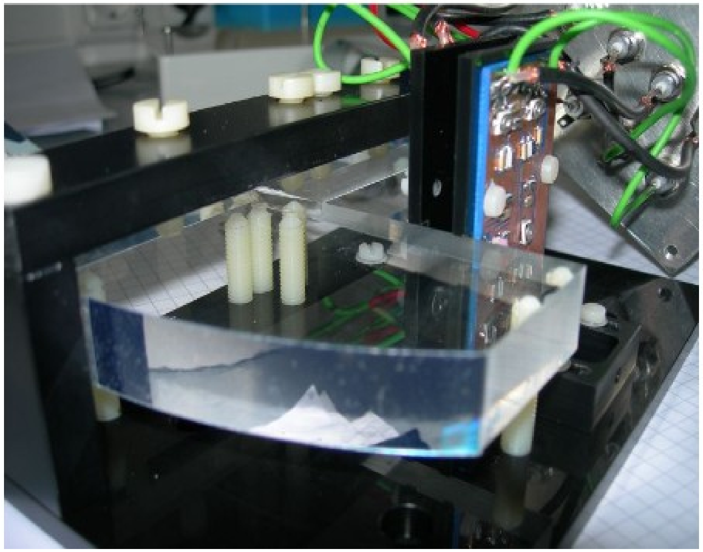
Poster, Klaus Föhl

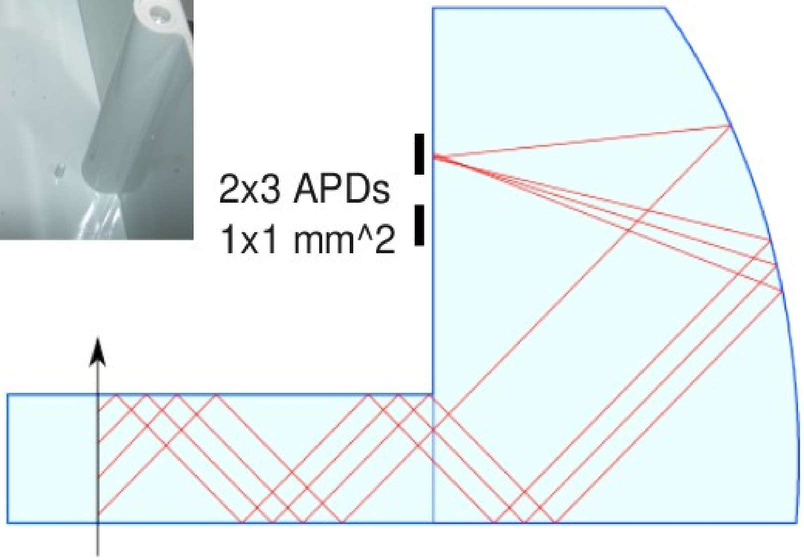

Start counter
Proton beam 2 GeV
CBM setups
TOP option setup
Focusing option setup
Barrel DIRC setup
Readout electronics

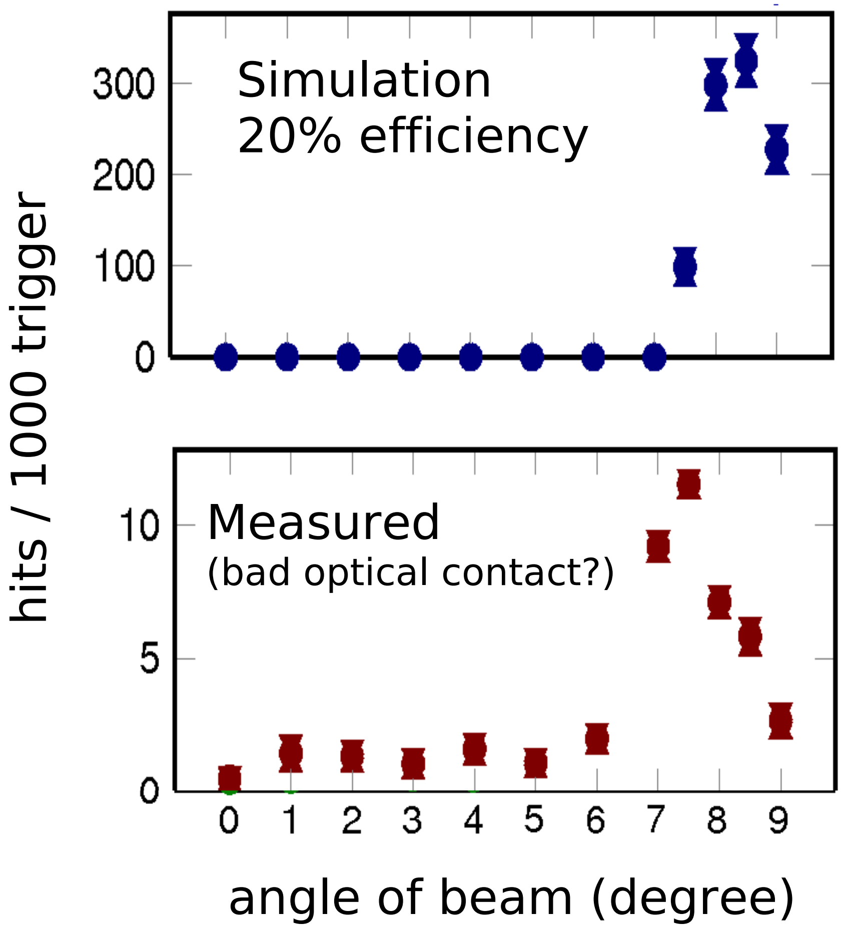
Radiator focussing light guide read out by APDs in Geigermode

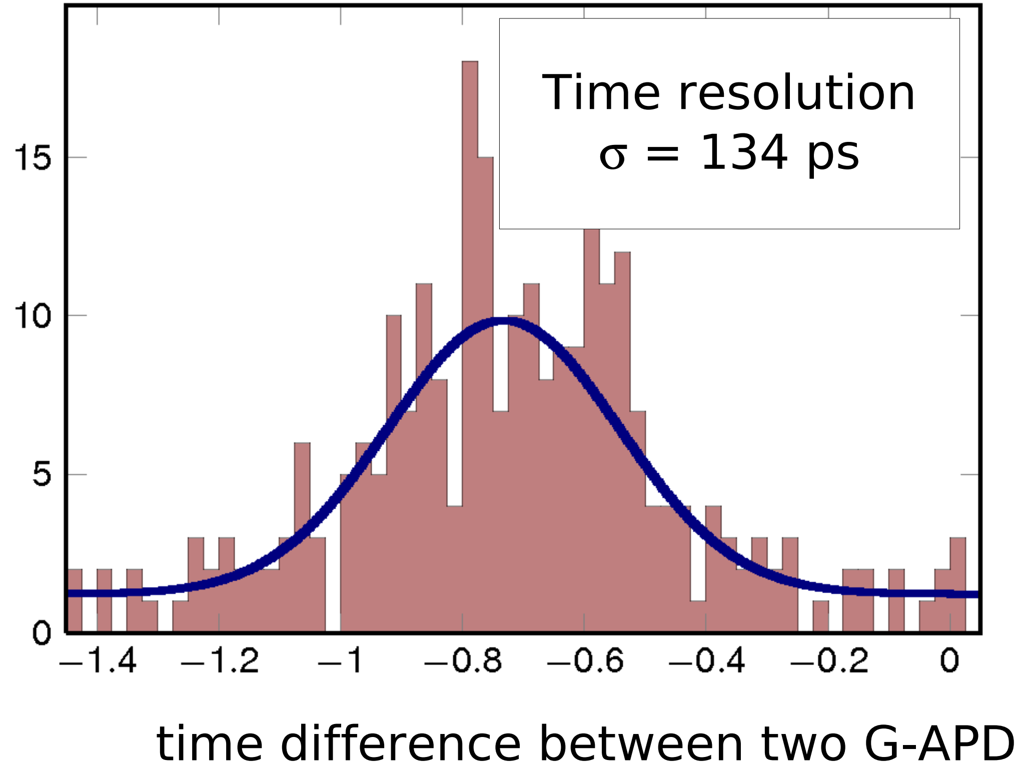
Small Prototype for Test

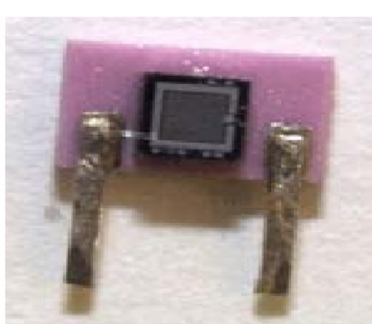


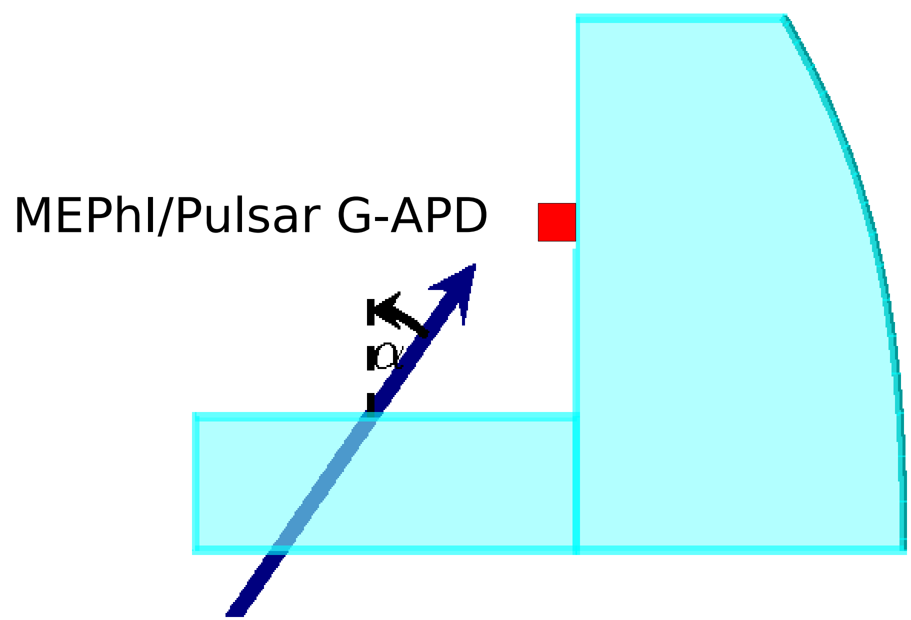




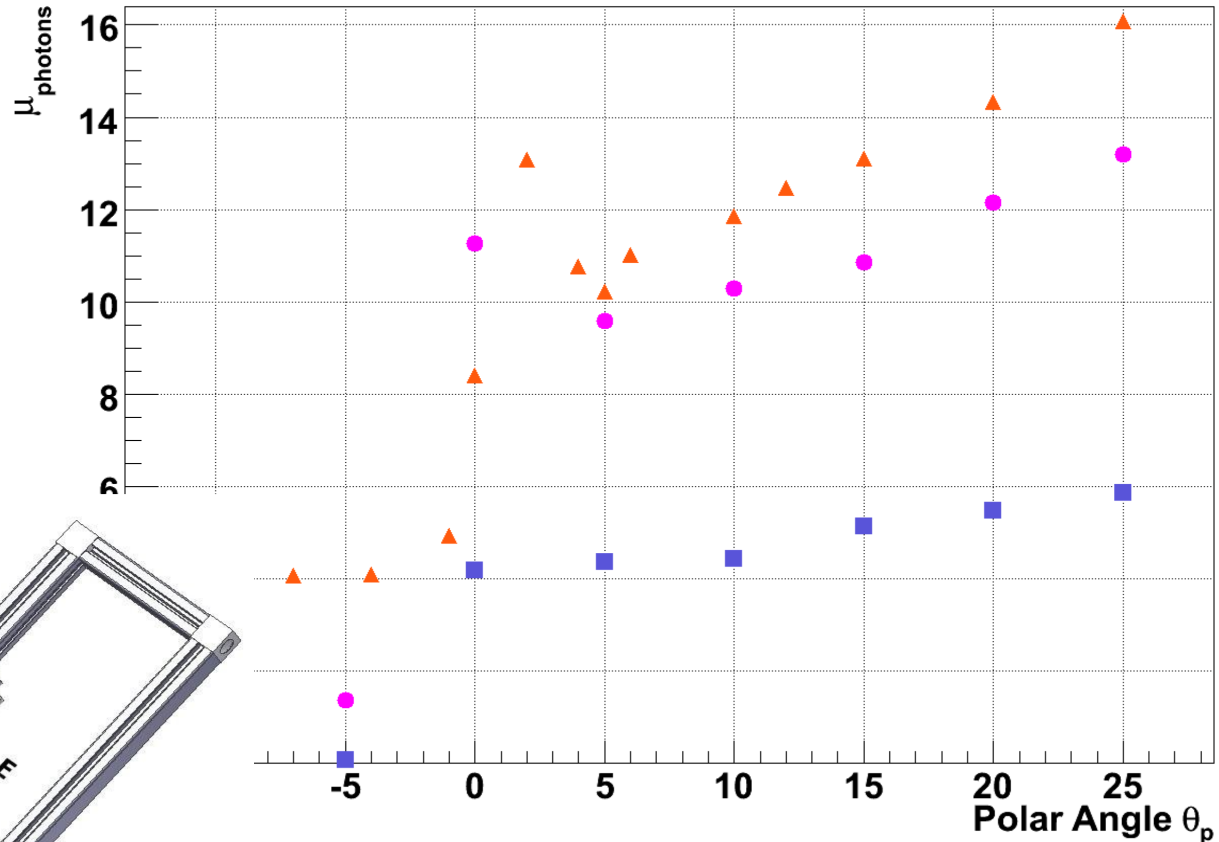

hits / 1000 trigger
Simulation
20% efficiency
300
200
100
0
Measured
(bad optical contact?)
10
5
0
0 1 2 3 4 5 6 7 8 9
angle of beam (degree)

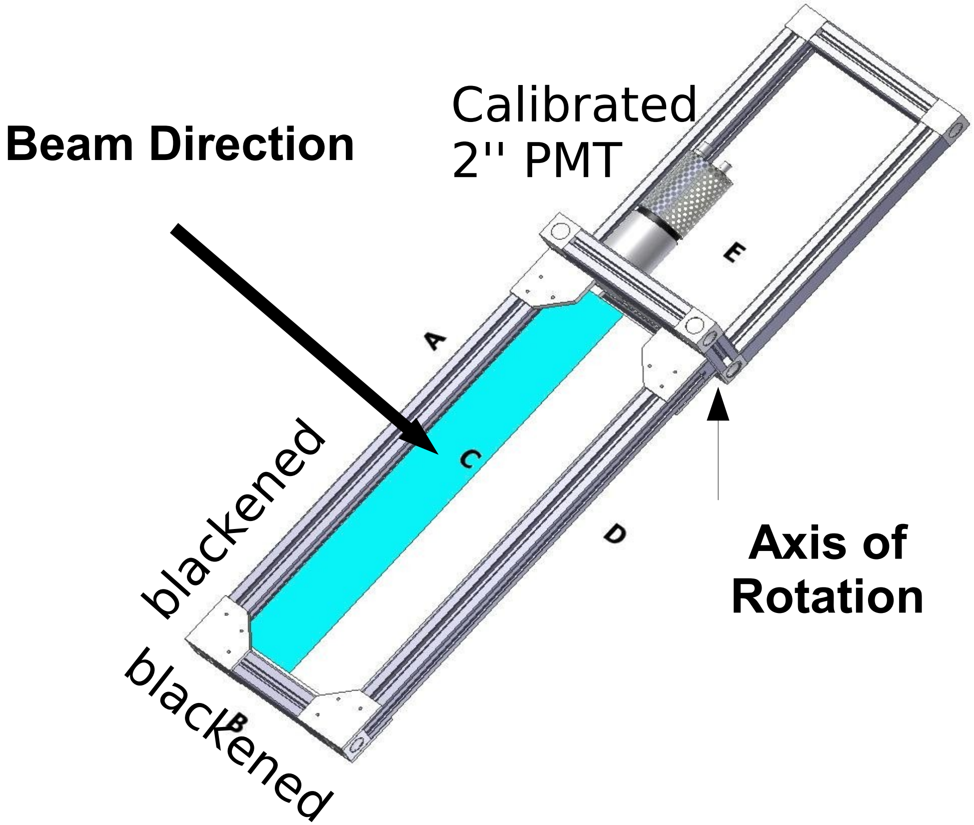

Time resolution
σ = 134 ps
15
10
5
0
−1.4 −1.2 −1 −0.8 −0.6 −0.4 −0.2 0
time difference between two G-APD




MEPhI/Pulsar G-APD
α

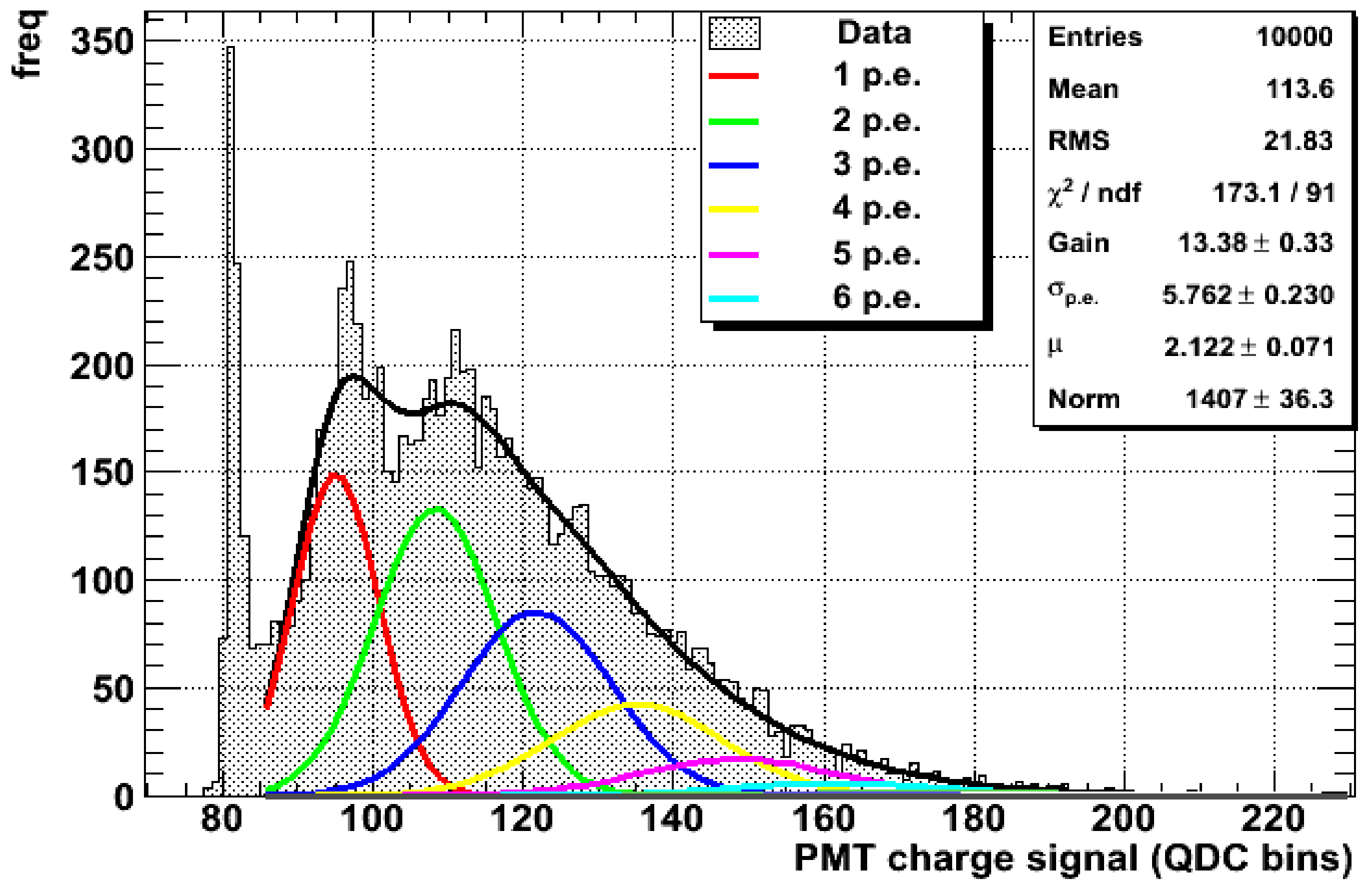
Focusing option: measuring photon yield of radiator





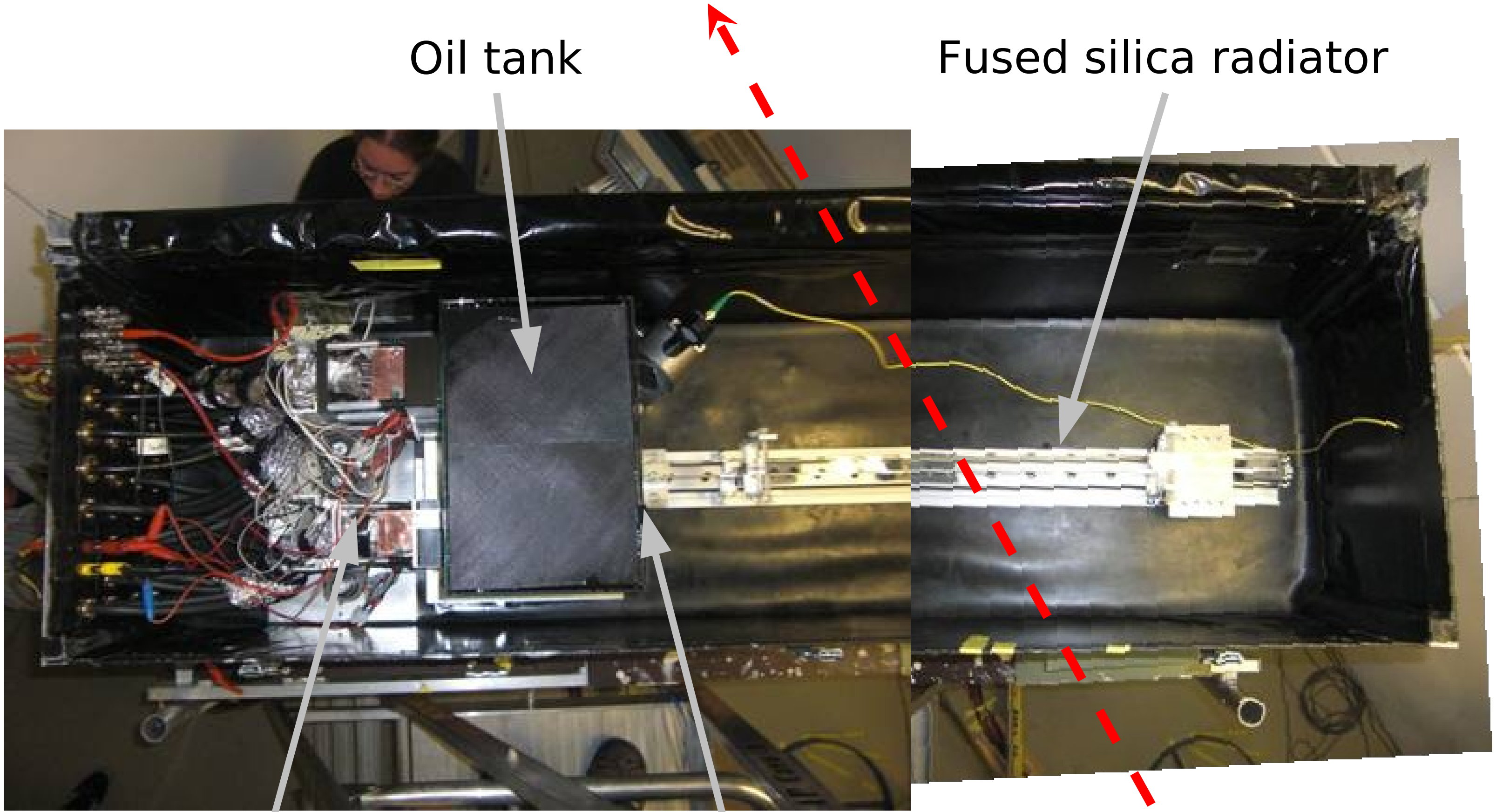
FLDD observed data, ▲, compared to simulated data for low reflection suppression, ●, and high suppression, ■.

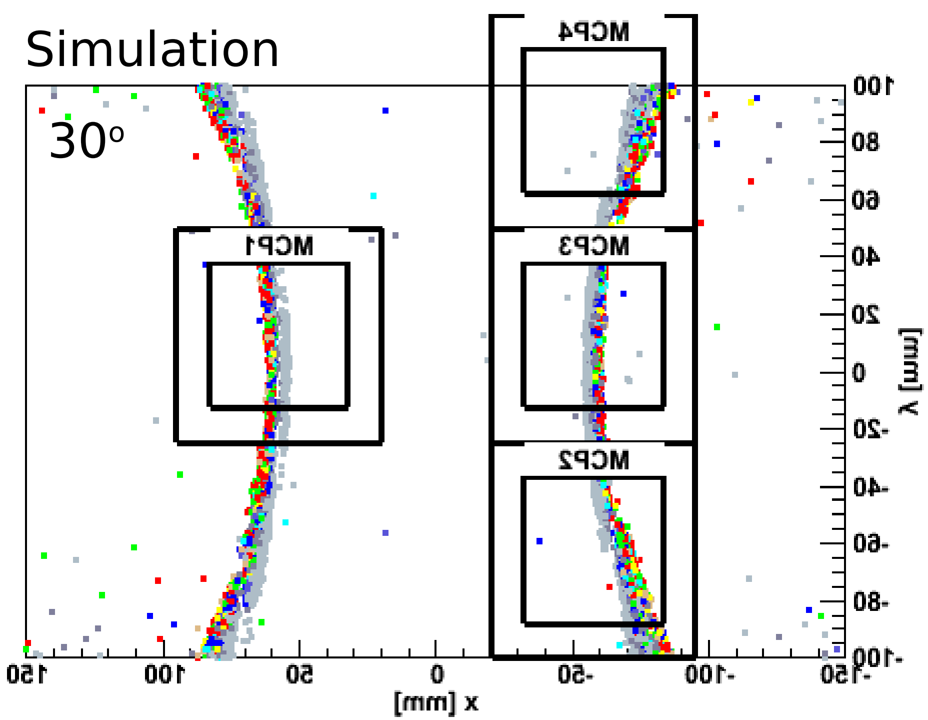
Focussing Disc DIRC - Calibration



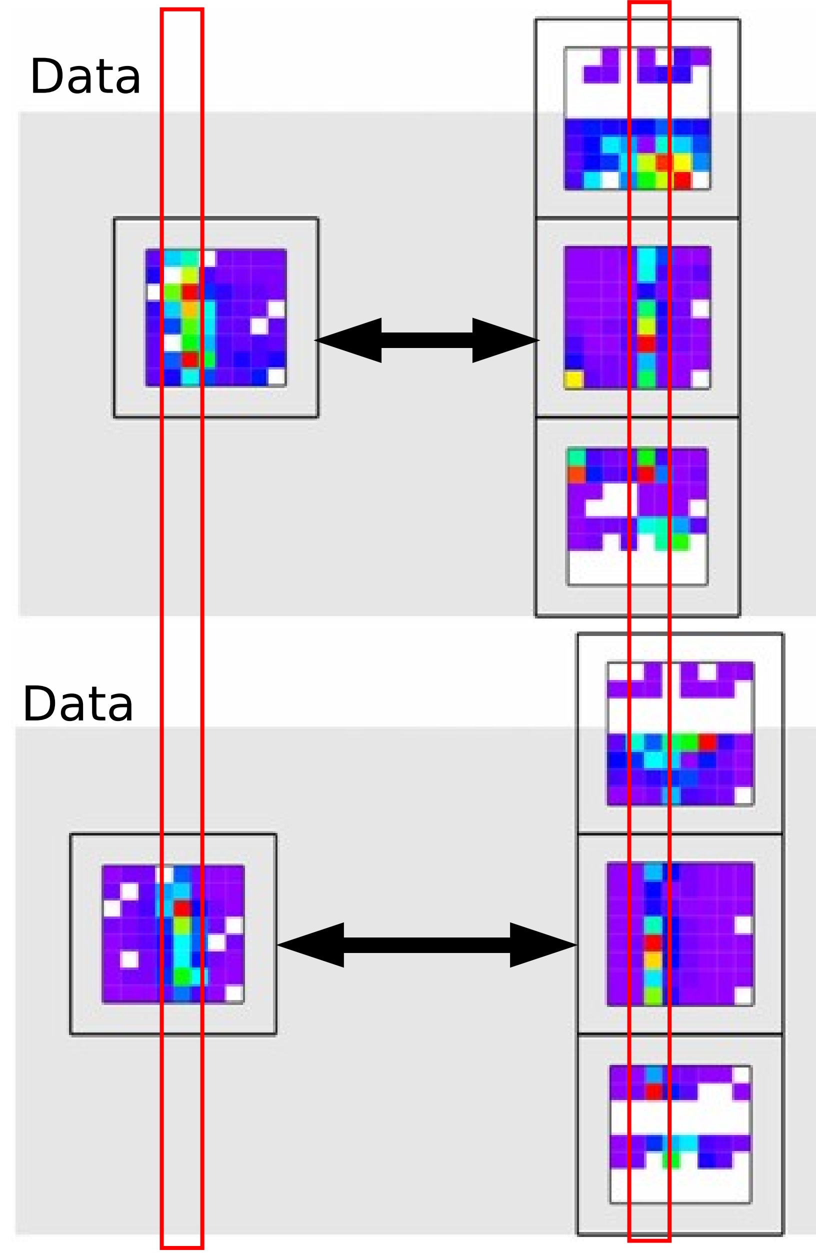
Multi-parameter fit required to describe observed signal in the PMT. Shown are contributions from different numbers of observed photo-electrons.

Barrel DIRC: Ring Imaging





, RICH 2



move MCP PMTs by 15mm each
→ does the ring stay in place?
(in box coordinates)

It does.

Summary

- PANDA includes two DIRCs for PID
    - Barrel DIRC similar to BaBar DIRC
    - Endcap Disk DIRC, several designs
- R&D activities
    - radiator quality, focusing optics
    - photon detectors, [readout electronics]
    - fast timing, chromatic correction
    - simulation, reconstruction...
- Test experiments for small scale prototypes

Start of FAIR construction: 2011

Planned start of PANDA installation in 2016

Opportunity for 1-2 more years of exciting DIRC detector R&D

Backup

Barrel DIRC Imaging